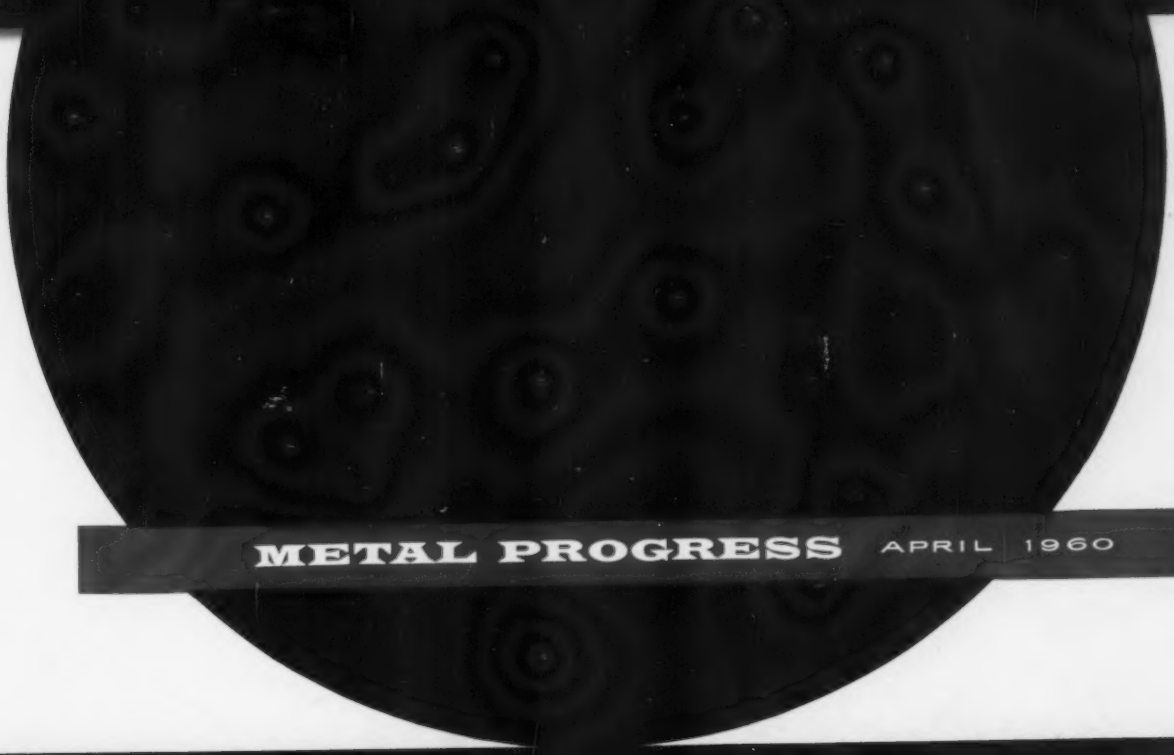
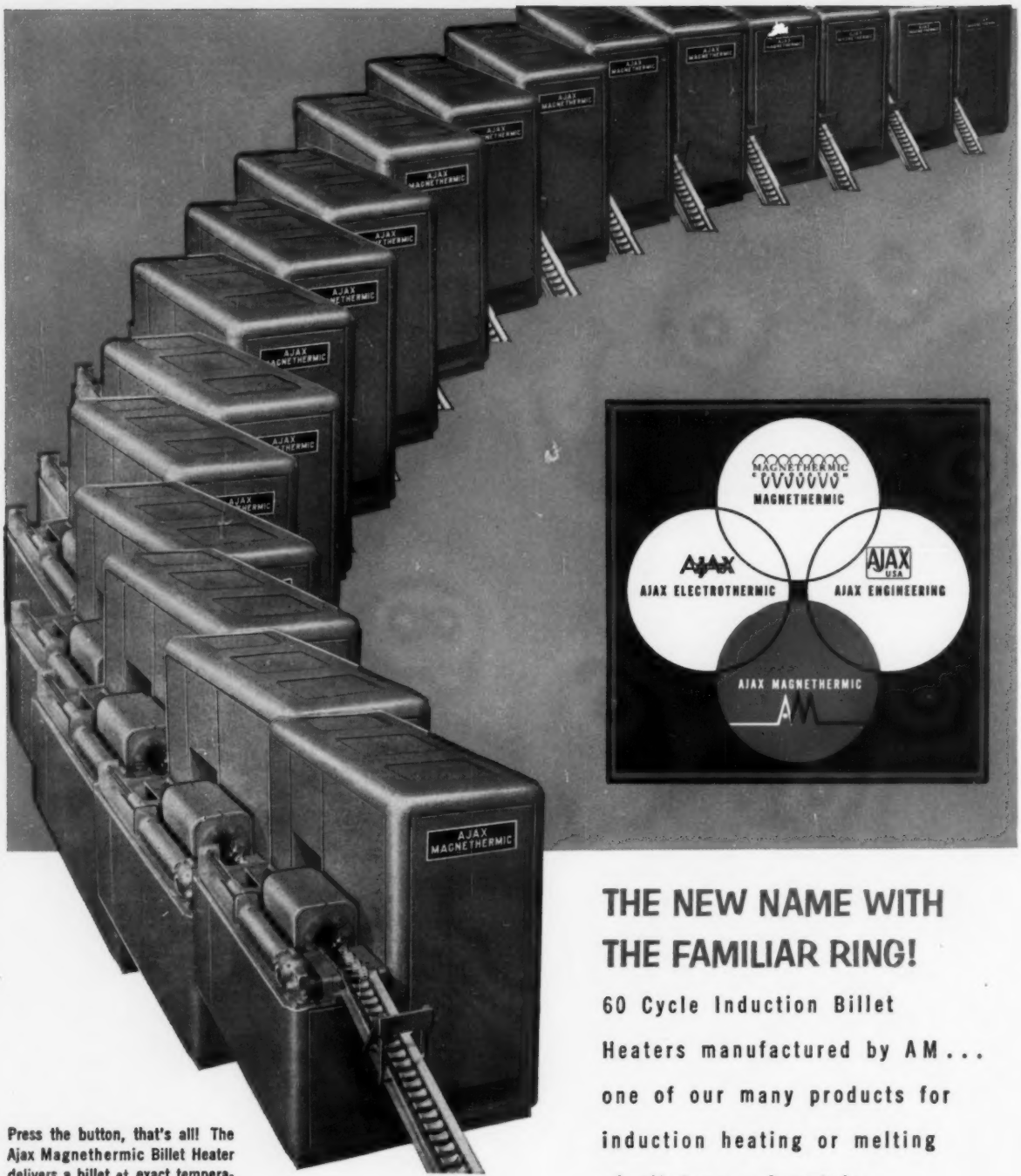


METAL PROGRESS APRIL 1960



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Metal Progress

April 1960 . . . Volume 77, No. 4

The blue light from Cerenkov radiation illuminates the core of the Army package power reactor at Ft. Belvoir, Va., shown on the cover. The plant has produced 25,000,000 kw-hr. of electricity since it went into operation three years ago this month. For additional details see p. 126.

Technical News in Brief

Spray Application of Vinyl Dispersion Finishes . . . N.A.S.A. Reports Progress in Tungsten Research . . . Navy Airs its Metallurgical Problems . . . Metal Statistics: Iron Powder and Zinc Recoup Losses . . . Simple Device Speeds Metal Sorting . . . Are Your Hand Tools Safe? . . . Notes on Corrosion From S.A.E. Meeting . . .Materials Progress in Nonmetallic Bearings and Ceramic Insulation . . . New Ideas for Production 65

Progress in Reactor Technology

Fabrication of a Zircaloy-2 In-Pile Pressure Tube, by J. G. Goodwin 93

Successful fabrication of Zircaloy-2 into a critical reactor component demonstrates that with special attention it can be formed into shapes by conventional methods despite its undesirable working characteristics. (F24, K1d, G17, T11; Zr-b)*

Recycling Zircaloy Scrap, by B. F. Rubin and R. F. Gessner 97

Large quantities of Zircaloy are used for cladding fuel elements and as structural components in nuclear reactors. To conserve material and to reduce costs, solid scrap and ingot conditioning chips can be treated and remelted. (A11d, B13; Zr-b, RM-p)

Data Sheet

Properties of Zircaloy-2, by Lester S. Rubenstein 100-B

Composition, mechanical and physical properties, corrosion, microstructures, bibliography. (P-general, Q-general; Zr-b)

Progress in Flame Hardening

Modern Practice of Flame Hardening, by M. R. Scott 69

Through suitable variations, any of the three methods for flame hardening now available (progressive, spinning and combination) can be used to harden the surface of practically any part. (J2h; ST, CI)

Case Histories of Flame Hardening 74

Rope drums, rolls, automotive bumper dies, all-welded gears, machine ways and machine screws are illustrated.

The Flame Hardening of Gears, by John T. Howat 76

Steel gears of almost any size can be economically flame hardened providing the proper procedure is employed. (J2h, T7a; ST)

Engineering Articles

The Earliest Days of Precipitation Hardening, by W. A. Mudge 79

During a European tour, an American pioneer in the field was able to uncover some little-known facts about the invention of the art and discovery of the scientific principles of precipitation hardening. (N7a, A2)

World's Largest Vacuum Induction Furnace, by J. W. Byrne 83

Construction and operation of the nation's first 5000-lb. vacuum induction furnace. Several engineering innovations make this a versatile installation. (W18a, 1-73)

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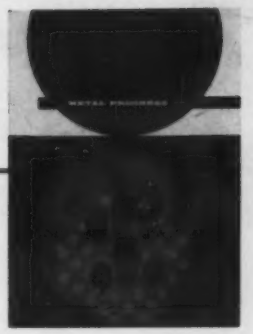

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How grid tray life was increased from 4 to 72 months

Electro-Alloys' knowledge of thermal fatigue extends service life 1700%

Figure 1 shows a grid tray used to move a solid cube of steel through a heat-treat furnace where side burners directed flame over the top of the tray, Figure 2. After 3-5 months' service, this tray would distort and fail, Figure 3. A photographic close-up of the failure is shown in Figure 4.

The user assumed the failure was due to inadequate pushing strength. With strengthened pushing ribs, the redesigned tray lasted only 2-3 months, half as long as the original design.

In view of this behavior, the user requested an Electro-Alloys design evaluation. The results are shown in Figure 5. *This new tray has a service life of 5-7 years!*

Pinpointing cause of thermal-fatigue failure

Electro-Alloys found that the *original tray* had been *overdesigned.* Extensive knowledge of the subtleties of thermal fatigue led to this conclusion.

Study of the furnace operation showed that the zones of heating and a heavy cooling concentration were the real causes of tray failure. They acted in this way:

On entry into the furnace, outside members of the tray heated more rapidly than inside members. As a result, expansion of these outside members was restricted by the cooler inside members. This set the stage for compression failure of outside members.

Farther in the furnace, inside members came up to temperature. But outside members had already forged in and were undersized. Now, expanding inside members subjected outside members to tensile stresses. This double reversal of stresses, compression then tension, during every cycle soon produced failure.

Any attempt to strengthen these outside members results in earlier failure because the increased mass leads to the metal fighting itself even more.

New design solves problem

The new design, Figure 5, called for raising the transverse ribs. This allowed the heated air to pass under the heavy die block. Through this simple change, it was possible to bring the die block to temperature more quickly and to eliminate the high temperature differential between outside and inside members of the tray.

The result is a 1700% increase in service from each tray.

Avoiding expensive thermal-fatigue pitfalls

Users and designers of heat-resistant castings are vulnerable, generally, to two pitfalls that lead to losses in service life and operating economy:

a. Assuming that an alloy operating well at 2000°F. will work just as well in a different application whose maximum temperature is only 1700°F.

b. Too much faith in the calculation of applied stresses as the measure of the casting's ability to withstand service conditions. This is reflected by increasing the size or number of restricting members . . . braces, gussets and tie rods.

These pitfalls are a natural outgrowth of the lack of information on thermal fatigue . . . the cause of 90% of all failures of heat-resistant castings.

Electro-Alloys is recognized as the leading authority on thermal fatigue and high-alloy casting design. Hundreds of case histories — such as the one reported here — and the widely published test data emanating from the Research Laboratory at Mahwah, N. J., are evidence of this.

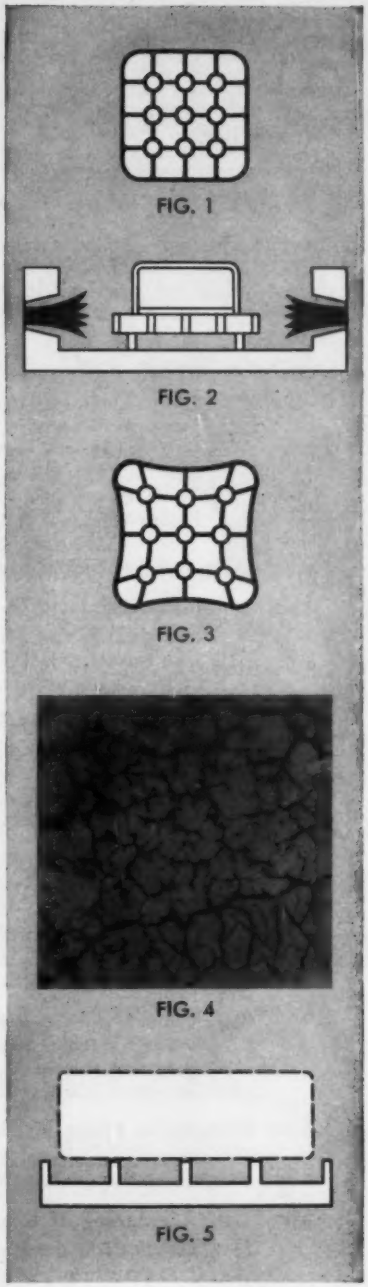

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

● *Most recent of these reports is "The Mechanism of Thermal Fatigue," by H. S. Avery. Copies of this study are available on request. Simply write to Electro-Alloys Division, 2014 Taylor Rd., Elyria, Ohio.*

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How to Get the Most From Solvent-Vapor Degreasing – Part I, by T. J. Kearney and C. E. Kircher 87
New equipment designed to use sprays, warm solvent baths, and ultrasonics has expanded the basic method so that an even better job can be done. (L12j)

New Eddy Current Test for Tubing, by Byron B. Burd 101
Small defects can be readily located in tubes by a new eddy current testing setup which contains circuitry that filters out background interference. (S13h, 1-52; 4-60)

Chromium Steels Remain Tough After Eight Years at High Temperature, by Merrill A. Scheil 104
Results of an unprecedentedly long series of exposure tests in operating equipment at 715 and 900° F. verify generally the conclusions reached 25 years ago from corrosion and stress-corrosion tests in the laboratory, and from a 15 months' run in petroleum equipment. (Q26s, R7a, N8; SS)

Flight in the Thermosphere – II. Materials for Nonmelting Heat Sink Systems, by William S. Pellini and William J. Harris, Jr. 113
Excellent thermal conductivity and high specific heat are the most important properties for heavy-wall heat sink applications. These properties enable rapid diffusion of heat generated at an aerodynamic surface into the interior of the material. (P11h, P12r; SGA-h)

Bonding Evaporated Metals to Stainless Steel, by A. S. Holik 116
Prizewinner in 14th Annual A.S.M. Metallographic Exhibit, Chicago, November 1959

New Iron-Base High-Temperature Alloy?, by G. K. Manning 117
Hot hardness curves for iron alloys containing 20% Cr with nickel, columbium, and carbon suggest excellent high-temperature strength. (Q29p, Q27a, 2-62; Fe-b, SGA-h)

New Uses for Stainless Steel, by George C. Kiefer 120
Fabricating techniques, new to stainless steel, are broadening its application in automotive, architectural, industrial and other areas. (T-general; SS, 17-57)

Power From Gas-Cooled Reactors, by E. E. Thum 123
In England much power is generated in reactors using natural uranium as fuel. American engineers believe that operating temperatures should be much higher, and so prefer enriched uranium oxide as fuel and use stainless steel or graphite for heat resistant containers. (W11p)

Special Report on Golden Gate Metals Conference
Attention is focused on high-strength steels, joining metals for high-temperature service and metallurgical problems in electronics.

High-Strength Steels for Missiles and Spacecraft, reported by G. K. Bhat 68-A

New Techniques Extend Potential for Brazing, reported by R. C. Bertossa 68-C

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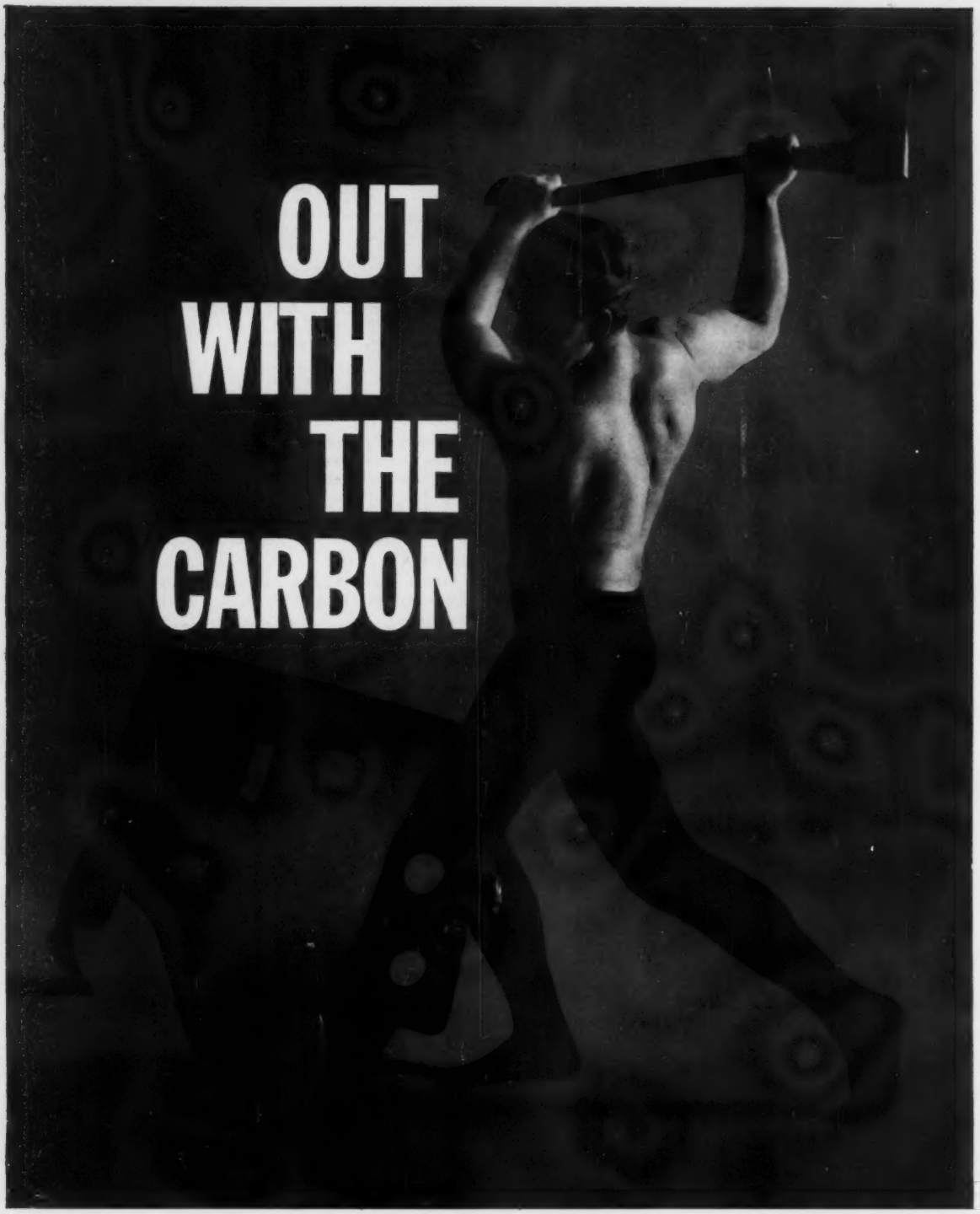

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The Wm. H. Eisenman Collection

In the months immediately after Bill Eisenman's death a number of contributions were made to a memorial fund. The Board of Trustees has now decided that the money, with future additions, shall be used to purchase old, rare and important books on metallurgy. This "William H. Eisenman Collection", to be treasured in the library at Society Headquarters, might eventually become so notable as to attract scholars and historians from all over the world. Chairman of the administrative committee is the well-known savant, Cyril S. Smith, professor at the Institute for the Study of Metals at the University of Chicago. The nucleus of this collection will be on display at the ceremonies dedicating A.S.M.'s new headquarters building at Metals Park in September 1960. Further contributions for this purpose by admirers of our late Secretary will be welcomed, either in money or incunabula.

What Is a Metallurgist?

Recently we made some remarks in this "Press Breaks" column about the desirability of choosing one's words precisely. The matter has more than academic importance. For example, what does the word "metallurgist" mean to John R. Citizen?

In a recent talk to a group of educators about what the A.S.M. was doing to attract more young men to the study of metallurgy, the Editor-in-Chief made the unguarded statement that the public image of a librarian was much more accurate than the public image of a metallurgist – whereupon he was sharply challenged by a svelte librarian present (or was it a "documentalist"?) who said the public picture was of a spinster with hair done up in a bun through which was stuck a pencil and over her head on the wall was a sign "Sh-h-h".

The only reply to this was a quotation from a 1955 McGraw-Hill book entitled "Occupations and Careers", by W. J. Greenleaf who signs himself "Specialist, Guidance and Student Personnel Section, U. S. Office of Education" (no less):

"The metallurgist is a professional engineer who analyzes ores."

No wonder only 2% of the engineering students in the United States are headed toward metallurgical degrees!

Earl Gabrielson, assistant plant manager of Kable Printing Co. (which manufactures *Metal Progress*), was in the Editor-in-Chief's office the other day and asked to see the microscope which was used to examine each issue as it arrived. Honest, a microscope is not needed to note the typographical sloppiness the modern printer often perpetrates. Now that the craftsman has practically disappeared from the craft, it takes incessant pounding to get a reasonably good product. Since the editors expend the utmost pains to approach a perfect magazine, we keep insisting that the printers also watch the little things. Maybe that's why *Metal Progress* has won its various awards for typographical excellence.

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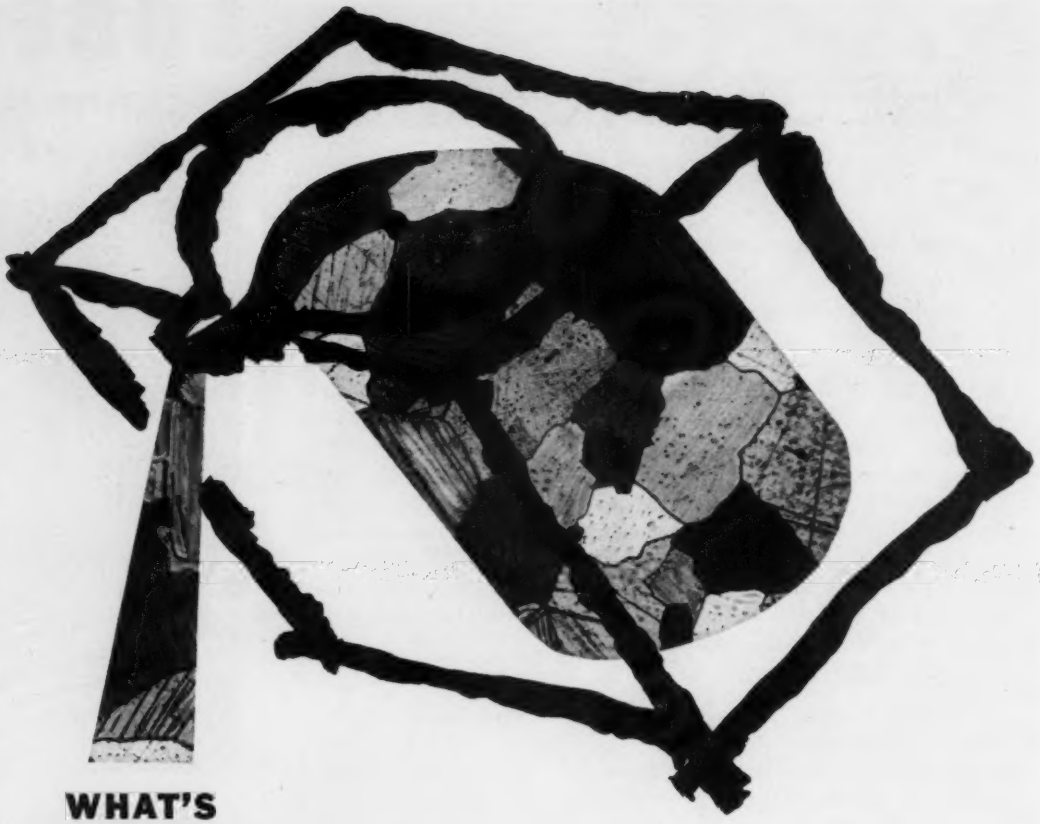

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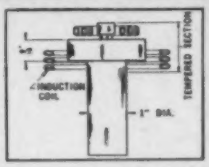
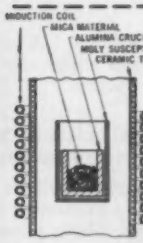


Punch Heads Selectively Tempered

Diagram shows arrangement for selectively tempering heads of alloy steel punches. The use of a combination type solenoid and pancake induction coil reduces hardness from Rc 55/56 to Rc 41/44, improving resistance to brittle fracture at the head of the punch. In this case a heating cycle of 55 seconds provides uniform tempering. A multiple position fixture, processing 4 pieces at one time, speeds up production.



Heating Non-Conducting Materials To High Temperatures

Laboratory analyses frequently require heating of non-conducting materials to temperatures of 3,000 to 3,500° F. in vacuum or special atmosphere. This can be accomplished by induction heating with the aid of a metal susceptor. Diagram shows the fusion of mica samples in an alumina crucible, using molybdenum susceptor. A ceramic tube surrounding the susceptor isolates the work for fusion in a vacuum. The molybdenum susceptor is heated by induction, which in turn, heats the crucible by radiation.

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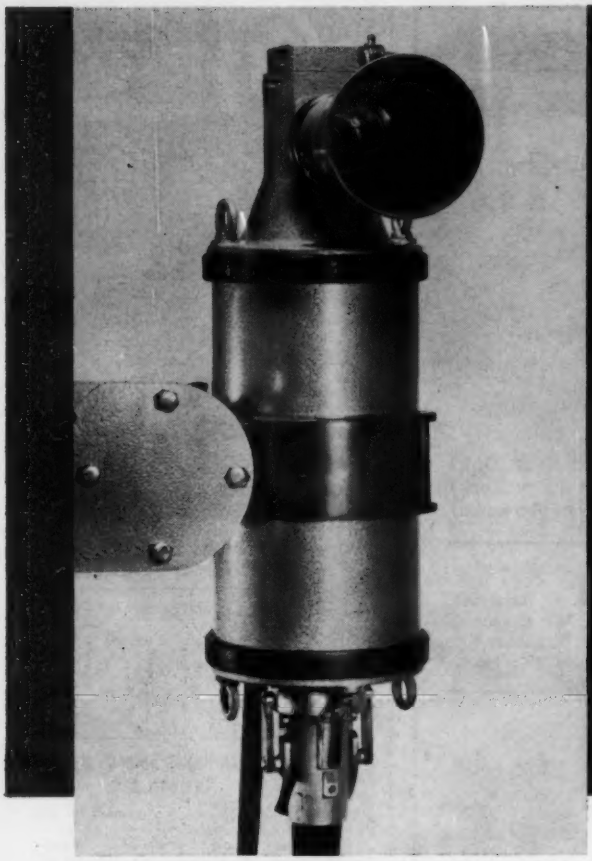

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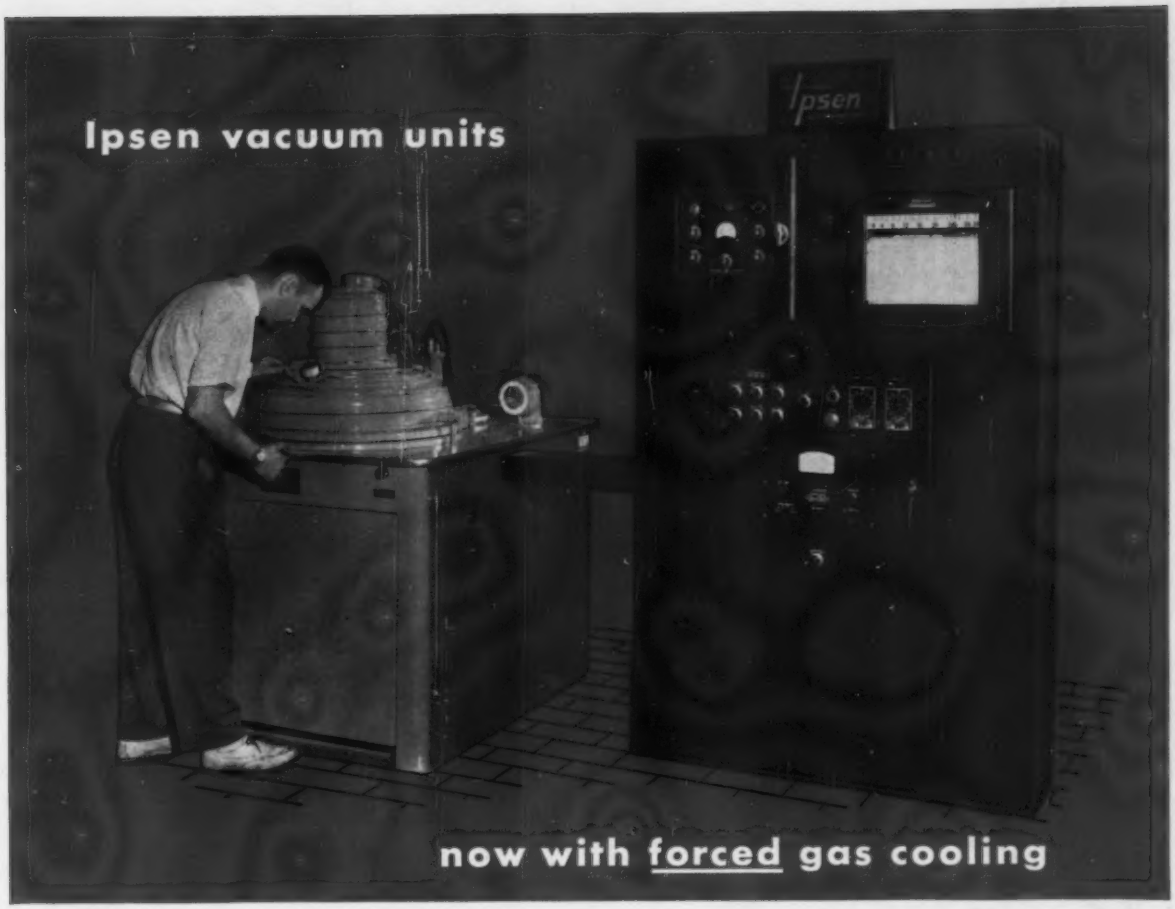

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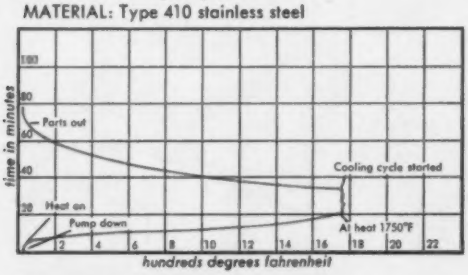
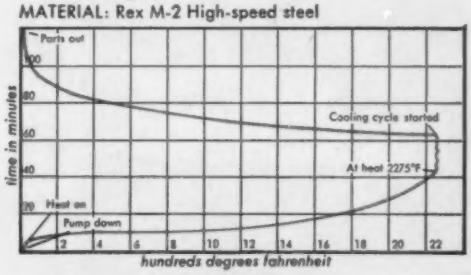


COMPLETE TIME CYCLE: 1 hour 8 min.
RESULTS: Rockwell C 42-43
APPEARANCE: Exceptionally bright

PARTS: Boring bars
MATERIAL: Rex M-2 High-speed steel



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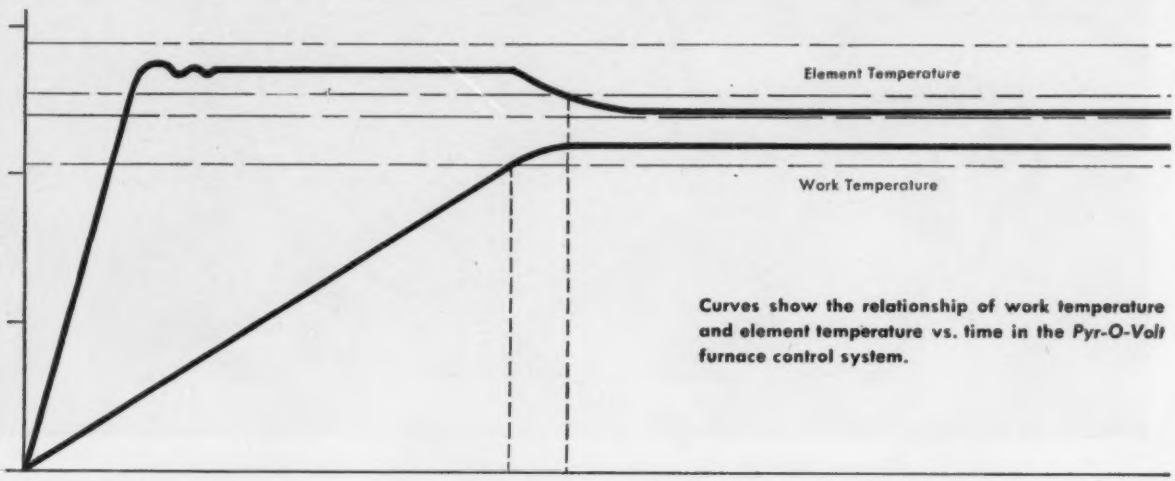
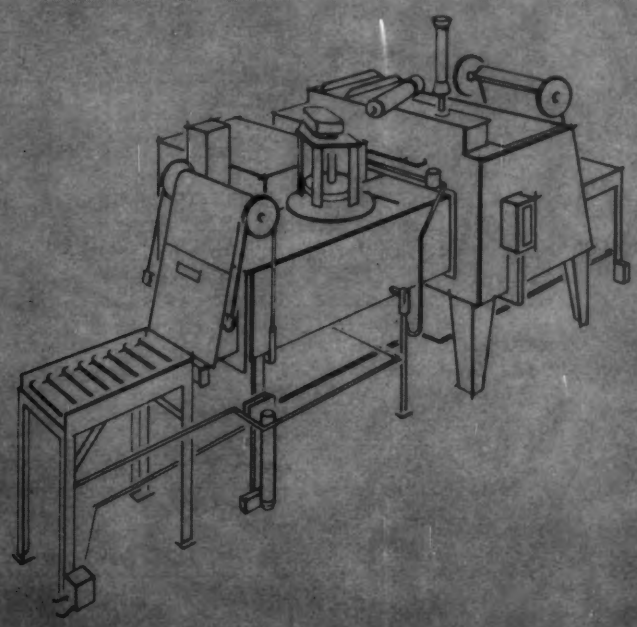
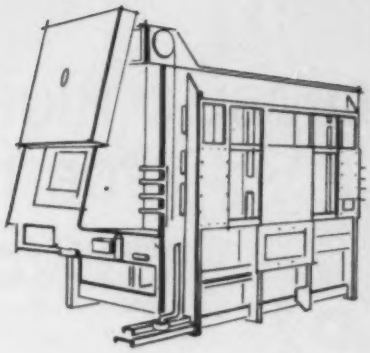
Electric furnace control overshoot, protects



Curves show the relationship of work temperature and element temperature vs. time in the *Pyr-O-Volt* furnace control system.



system prevents heating elements



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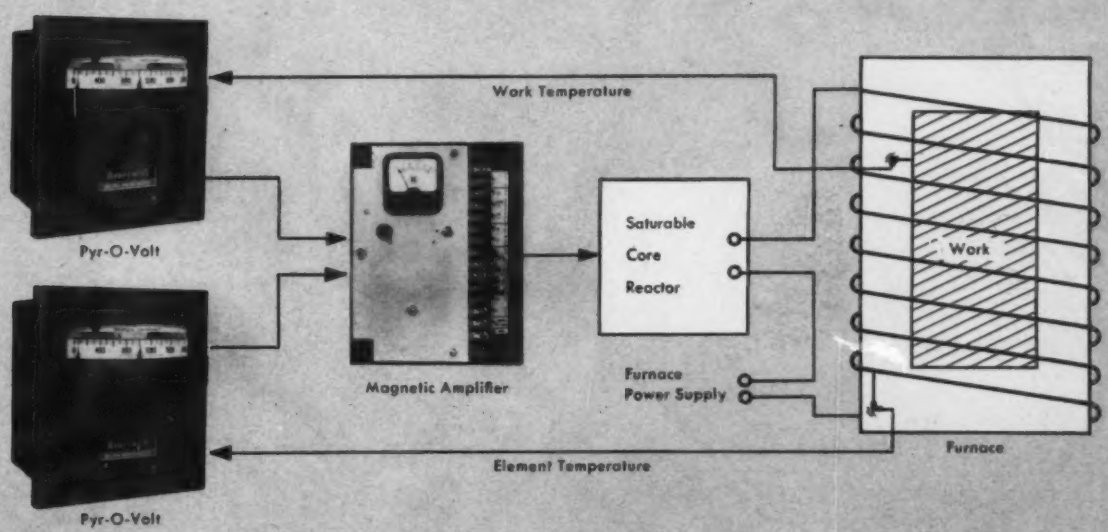

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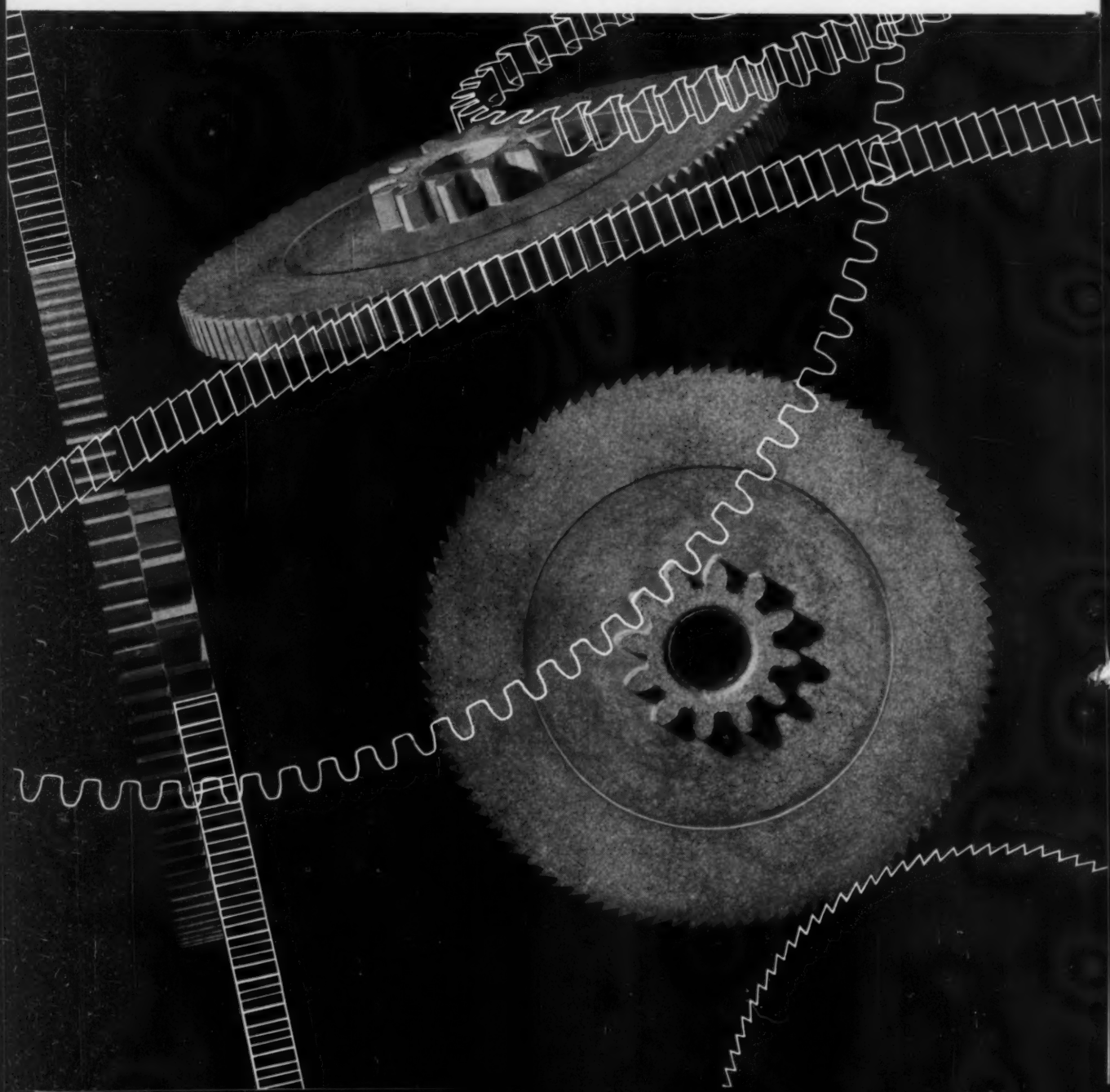

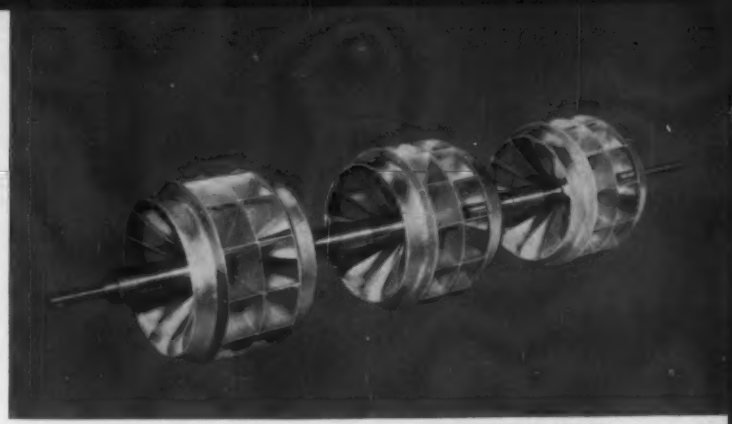

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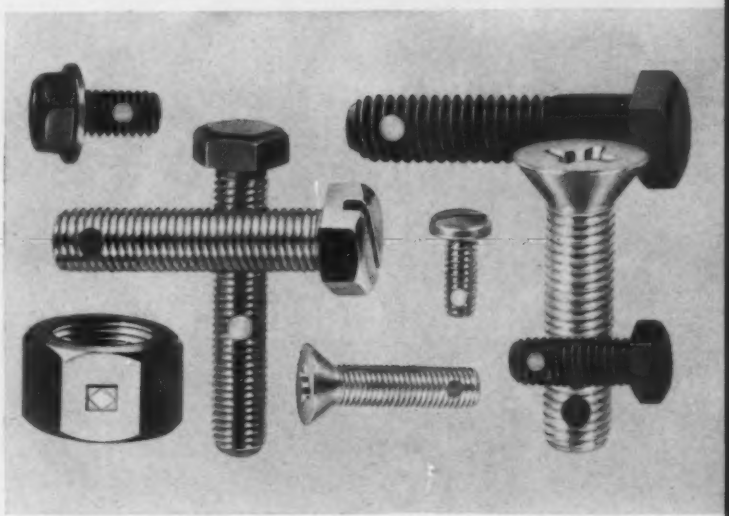

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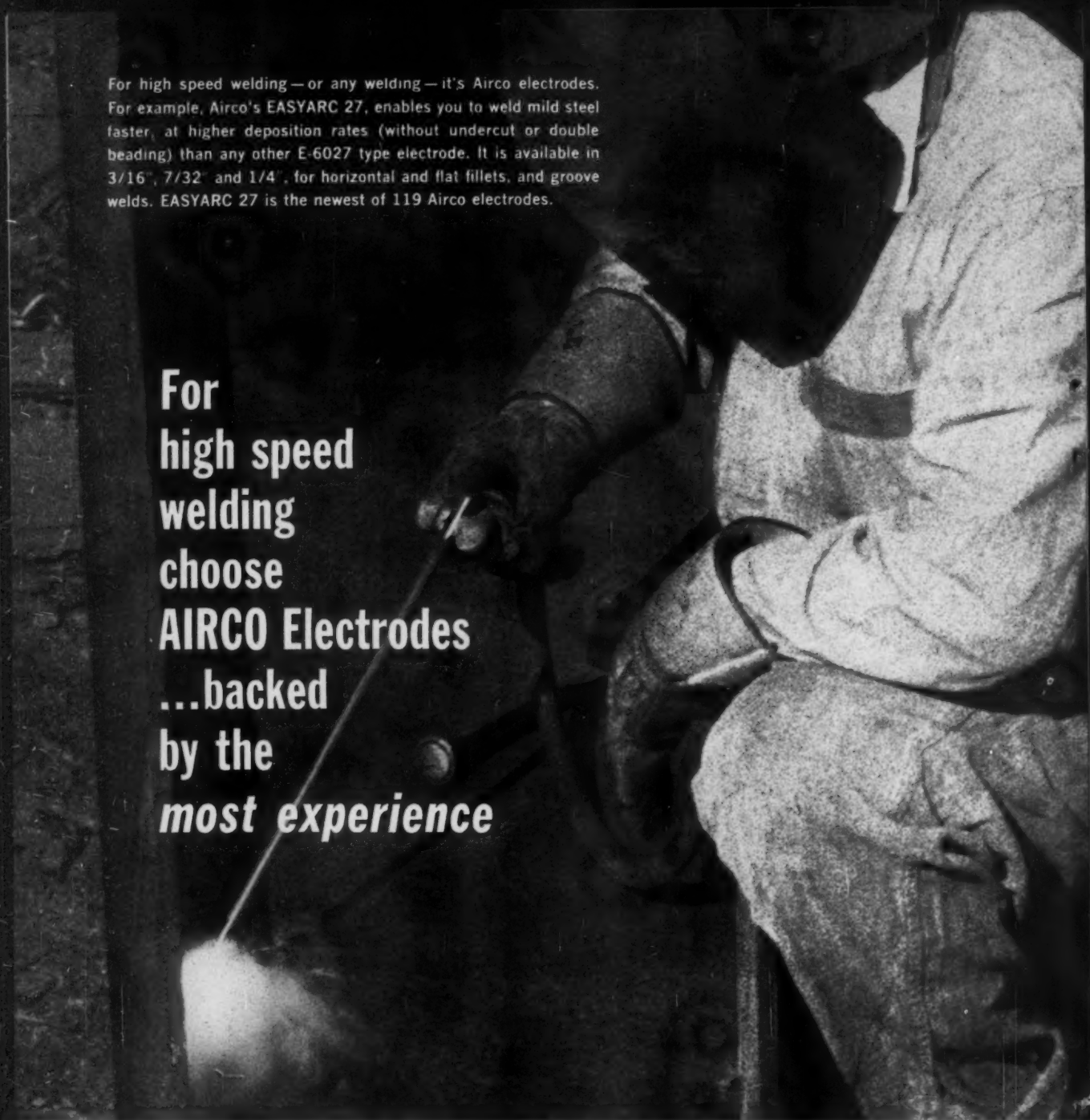

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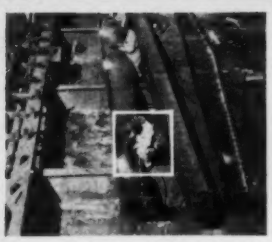

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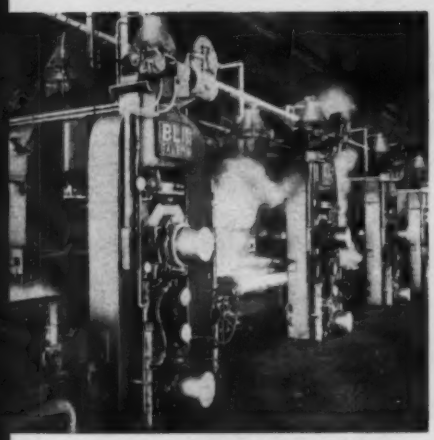

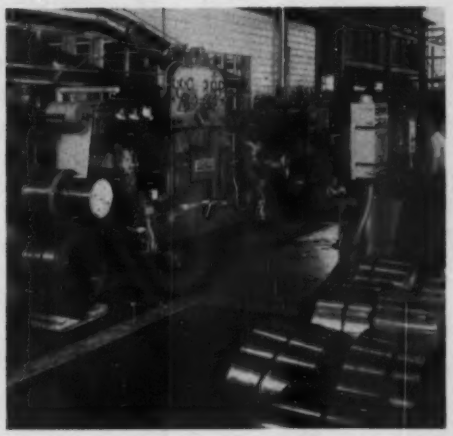

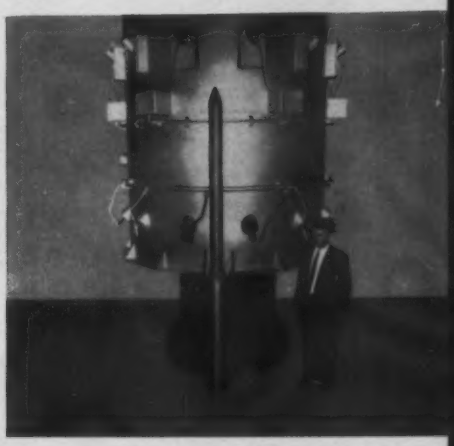

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This is a single fiber derived from the wood of a Douglas fir.

Latin name: Pseudotsuga menziesii. Dimensions: spectacularly minute. Length: 0.165". Cross-section area: 0.318×10^{-4} sq. in. It makes a common straight pin look like a flag pole in comparison.

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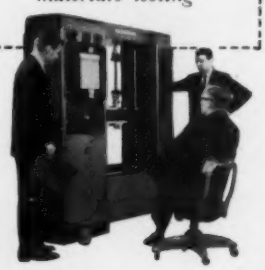

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APRIL, 1960
Vol. 7 No. 1

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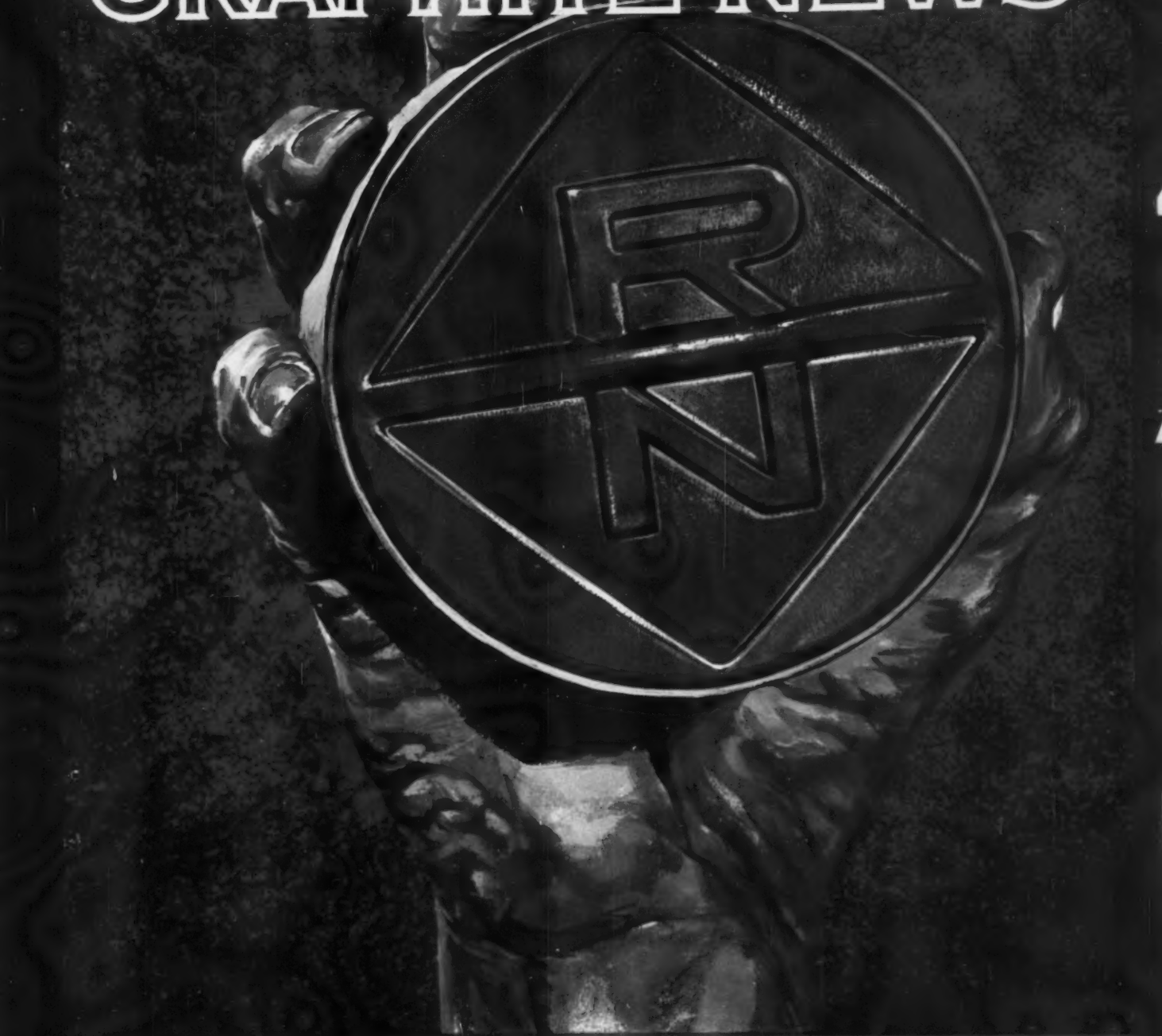

R-N BRIQUETTES...an electric furnace charge material of uniform composition

By W. R. Weaver

R-N BRIQUETTES...an electric furnace charge material of uniform composition

W. R. WEAVER, Director,
Steel Conservation and Quality Control
Republic Steel Corporation

The need for a suitable charge material from direct reduction of iron ores – for both electric and open hearth furnaces – is more pressing today than it has been in the past several years. The R-N Process – a joint project of Republic Steel Corporation and National Lead Company – has to date produced a large quantity of briquettes which have undergone intensive testing. These briquettes offer electric furnace steelmakers the following advantages.

- **A charge material produced from either low or high grade ores.**
- **A charge material that is easy to handle and store.**
- **A charge material that can effectively replace up to 60% of ordinary heavy scrap grades.**
- **A charge material of uniform composition.**
- **A charge material with the stable cost of a manufactured product such as pig iron.**
- **A charge material low in deleterious impurities.**

Introduction

In the steel industry today, one of the surest paths to success with a new material is to provide a product that can be handled in less time and with less care than the material it replaces. R-N briquettes, with a bulk weight of 225 pounds per cubic foot and good strength, permit easy handling and storage because of very small space requirements. An equally favorable factor is that briquettes can be loaded easily into buckets or boxes for charging.

The R-N briquette – a product of directly reduced ore in the R-N Process – appears after numerous tests to be an efficient and effective charge material for the electric furnace. The product can be produced from either low or high grade ore, and offers many advantages as a replacement for up to 60% of ordinary heavy scrap grades in electric furnace operations.

Melters are provided with a charge material with both uniform density and electrical conductivity. This makes for improved operations because nonconducting spots are

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View of the rotary kiln at the Pilot Plant in Spaulding, Alabama.

eliminated from the charge—a very important factor where heavy power is employed for melt-down.

These briquettes are uniform as to composition and are free from harmful incidental alloying elements. This means melters can proceed with much more speed toward the completion of each phase of the melting operation. Freedom from dirt and contamination results in smaller slag volumes. Even where molten pig iron is used, slag volumes are a problem because of the presence of the slag-forming elements such as silicon and phosphorous.

In addition to uniformity of product, industry gains a charge material that will be uniform in price. The cost of producing R-N briquettes cannot be generalized because these figures are associated with a given location and with the treatment of a given type of raw material. However, the product that R-N briquettes offer the steelmaking industry is a charge material of uniform cost comparable to a manufactured product such as pig iron.

ADVERTISEMENT

R-N Briquettes Have Been Thoroughly Tested

To date, approximately 60,000 tons of briquettes have been produced at the Pilot Plant at Spaulding, Alabama. The material has been tested in substantial quantities in the blast furnace, in the open hearth, and in the electric furnace. This article covers testing procedures and results in Republic Steel Corporation's electric furnaces.

Two major melting tests (employing a total of approximately 3,385 tons of R-N briquettes) were conducted in Republic Steel Corporation's Chicago District electric furnaces. The first test was carried on in a 20′ shell – 85 ton, top-charge electric furnace from February 18, to April 14, 1957. The second test was conducted in a 22′ shell – 135 ton, top-charge electric furnace from September 18, to October 10, 1958. In both instances, R-N briquettes were utilized as a straight replacement for scrap with no pig iron being employed.

Melting Test Number One

A total of 2,064 net tons of briquettes produced from Port Henry concentrates were shipped to Republic Steel Corporation's Chicago District for melting tests in an electric furnace. The instructions to the melt shop were "to examine the melting characteristics of R-N briquettes as a straight replacement for scrap in an electric furnace." A number of heats were made using varying percentages of R-N briquettes. The results of these heats were compared to those from companion heats in which no R-N was charged to determine the differences in the melting performance as the percentage of scrap replacement by R-N briquettes in the charge was increased from 20%, through 30%, 40% and 50%, up to 60%. It should be stressed that the data presented here are centered on the 40% level, which was the level decided upon by operating supervision as the one most desirable for the accumulation of data.

The briquettes used were 3¾″ diameter round slugs, 3″ to 4″ thick, weighing from six to seven pounds each. The top and bottom surfaces were flat and parallel, creating a strong tendency to nest or stack inside the electric furnace.

TABLE I

R-N Melting Test Number One

All Cold Charge — 40% R-N — 20′ Shell — 85-Ton — Top-Charge Furnace

Summary of Operating Data

Per Heat — Averages of 13 Heats	Control Heats	R-N Heats
Materials Charged — Pounds		
No. 1 Heavy Melt	186,000	113,600
R-N Briquettes	—	72,600
Total Scrap	186,000	186,200
Carbon	738	2,269
Power — K.W.H. Per Ton		
Charge to Melt	484	531
Charge to Tap	525	576
Times — Hours		
Adjusted (Less Delays)		
Charge to Melt	3.84	3.95
Charge to Tap	4.86	4.94
Patching Time	24	21
Tons Per Hour (Total Tapped)		
Charge to Tap — Actual	17.8	17.1
Tap to Tap — Actual	16.0	15.4
(Less Delays)		
Charge to Tap	19.00	18.33
Yields — %		
Gross Product Yield	94.13	93.33
Pounds Per Ton — Total Tapped		
Feed Ore	80.5	58.8
Burnt Lime	80.0	91.1
Chemistry — Steel		
Carbon at Melt	0.26	0.29
Carbon Drop — Melt to Tap	0.10	0.06
Manganese at Tap	0.19	0.14
Final:		
Phosphorous	.010	.012
Sulphur	.032	.030
Total Incidental Alloys	.38	.32
Slag:		
At Tap: FeO	22.29	23.61
TiO_2	0.57	2.61

Data from the first test are shown in Table I. In general, the R-N briquettes were observed to perform very similarly to regular heavy melting scrap such as crops or bloom butts. The advantages and liabilities due to the chemical and physical nature of the R-N product are shown in Table II.

Heat Time (charge to melt or charge to tap)	Stand-off
Bottom Repair Time	Stand-off
Power Consumption	Slight increase
Carbon required in charge	Slight increase
Ore Consumption	Saving
Metallurgical yield	Stand-off
Melt-in phosphorous	Advantage
Melt-in sulphur	Advantage
Total residual tramp alloys	Advantage

Table II. Advantages and liabilities of R-N material due to chemical and physical nature of the product.

Lower than normal yields were expected for two reasons. First, clean electric furnace melting scrap is generally conceded to be about 98% Fe, whereas the R-N material used averaged 95.30% Fe when unloaded into stock. Second, the R-N heats were under-charged deliberately to prevent any spillage that might occur due to the gentle boiling action caused by iron oxides present in the R-N material. The briquettes contained 8.3% of the iron as oxides in their various forms. In spite of this, the slags produced were not very different from those of the all-scrap heats and the bath boiling action produced a desired circulation of the metal. A point of interest to melters and furnace operators is that such action is favorable to the development of uniform temperature throughout the bath and speeds up removal of carbon.

The iron oxides contained in the R-N briquettes provided self-oreing characteristics. This meant that when R-N product was used as a charge material to replace scrap, if all other factors were maintained in balance, lower melt-in carbons would result. It was necessary, therefore, to charge supplemental carbon in the R-N heats. Broken electrodes were used for this purpose.

The pounds of ore consumed per net ton of steel tapped are consistently lower on the R-N than on the comparison heats. In spite of this, as noted above, melt-in carbons are generally lower.

It has been assumed that regularly established shop practices produced satisfactory melt-in carbons. For the R-N heats to be melted at carbon levels equivalent to the regular heats, even less ore than actually used would have been required.

Table I shows that heats made with R-N briquettes produced lower values for sulphur and total residual alloys than did regular scrap heats. These reduced levels are a definite advantage for the R-N heats over the regular scrap heats.

A car being loaded with R-N briquettes for shipment to Republic Steel Corporation's Chicago District for melting tests in an electric furnace.

Melting Test Number Two

To supplement and substantiate the data obtained during the first tests, a second series of test heats was scheduled during September and October of 1958.

Because of shop operating conditions, one important factor had to be modified in the second test. Since the time of the first test, three electric furnaces had been enlarged from 85-ton to 135-ton rated capacity. Only the latter furnaces were available at the time of the second test. This difference in furnace capacity in the two tests must be kept in mind.

A total of 1321 net tons of R-N briquettes produced from Port Henry concentrate were melted in twenty heats producing 3,030 net tons of ingots. The material was similar chemically to that used in the first test, but the physical shape of the briquettes had been modified. The top face of these briquettes was curved and hence the top and bottom faces were no longer parallel. A minimum tendency toward nesting and stacking inside the furnace was observed as a result of this physical shape modification.

The entire test pattern was designed to improve quality of the data obtained over that of the first test. Particular stress was applied on yield and power consumption data. All the metal tapped was weighed and ingots were weighed individually on a specially installed scale. Skulls, spills and even pit scrap were weighed. Short ingots or butts were measured. Specially designed power monitoring and data logging equipment was installed to provide a reading every minute on the power consumed by each individual electrode. Meters were carefully calibrated and presented readings within an accuracy of 1%. A special observer supervised the weighing of all materials, both charged and produced. A second observer was assigned to the power monitoring equipment, and an experienced metallurgical observer covered and logged all details of the furnace operations. All of these activities were supervised on a twenty-four hour basis.

Heats were made in "blocks" of five heats each. An equivalent number of regular or "control" heats were made. The test blocks of five heats each were alternated between R-N and control heats to insure balancing and randomizing the test conditions and to avoid bias which might otherwise result. This "design of experiment" afforded subsequent analysis of the accruing data on a sound statistical basis and the resultant formulation of conclusions and interpretations with specific degrees of confidence.

A summary of operating data appears in Table III.

TABLE III

R-N Melting Test Number Two

All Cold Charge — 40% R-N — 22' Shell — 135-Ton — Top-Charge Furnace

Summary of Operating Data

Per Heat — Averages of 20 Heats	Control Heats	R-N Heats
Charge Materials — Pounds		
Heavy Bloom Crops	119,730	—
Other Scrap	186,370	190,545
R-N Briquettes	—	119,486
Total Scrap	306,100	310,031
Burnt Lime	5,565	8,395
Carbon	1,020	3,335
Feed Materials		
Liberian Ore	3,950	4,528
Burnt Lime	3,562	2,205
Total Weight Melted	320,197	328,494
Total Metallics	314,708	318,813
Power — K.W.H. per Ton:		
Good Ingots Only	478	505
To Melt Total Charge	383	419
Total Weight Tapped	448	485
Times — Actual — Hours		
Charge to All Melted	4.50	4.73
Charge to Tap	5.90	6.04
Tap to Tap	6.51	6.50
Fettling Time	0.46	0.43
Adjusted (Less Delays)		
Charge to All Melted	3.94	4.21
Charge to Tap	5.34	5.50
Net Time Power To Furnace:		
Power on to All Melted	3.52	3.74
Power on to Tap	4.71	4.77
Product — Pounds		
Good Ingots Only	284,575	290,753
Total Metal Tapped	302,626	303,040
Pounds Per Ton — Total Tapped		
Feed Ore	28.84	30.46
Burnt Lime	60.29	68.72
Carbon	6.74	21.98
Yields		
Good Ingots Only	90.49	91.20
Gross Product Yield	96.20	95.05
Tons Per Hour (Total Tapped)		
Actual: Charge to Tap	26.03	25.30
Tap to Tap	23.60	23.45
Net: (Less Delays)		
Charge to Tap	28.53	27.72
Chemistry — Steel %		
Carbon at Melt	0.466	0.494
Manganese at Tap	.296	.194
Carbon Drop — Melt to Tap	.133	.174
Final:		
Carbon	.437	.442
Manganese	1.119	1.099
Phosphorous	.0161	.0163
Sulphur	.0353	.0300
Total Incidental Alloys	.339	.262
Slag:		
At Melt: FeO	17.87	15.07
At Tap: FeO	17.31	18.43
CaO	41.48	45.99
MgO	6.65	5.78
SiO_2	16.26	14.56
Al_2O_3	3.95	4.13
P_2O_5	.65	.69
V-Ratio	2.496	2.858

All heats, both control and R-N, were produced under the 100% scrap practice; no pig iron, either hot or cold, was employed.

On all control heats, 40% of the total scrap charged was composed of clean bloom butts or heavy crops. On the R-N heats this class of scrap was replaced with an equal amount of R-N briquettes, thus affording a direct replacement of a specific and stable scrap of known quantity. All heats comprising the test were melted for the same grade of steel and poured in the same size molds.

The results of the second test fortify and validate the conclusions drawn from the initial test. The magnitude of many factors was at a different level than in the original run due to the larger size furnace used and to the greater precision obtained in product weights. When the R-N heats are compared to the control heats, all criteria studied will be found to be in the same "direction" and by roughly the same relative order of magnitude as in the initial test run.

R-N as Straight Scrap Replacement

The data from both tests indicate that in electric furnace operations using an all scrap charge, R-N briquettes are a thoroughly satisfactory substitute for ordinary grades of heavy melting scrap, up to 60% of the scrap charge.

No difficulties were experienced in furnace operation. Heats appeared normal in all respects. A little more power was required to melt the total balanced R-N charge than to melt the scrap charge which it replaced. Most heats required more than the customary amounts of burnt lime. Feed ore consumption was entirely a function of the melt-in and required tapping carbons. The iron oxide content of the R-N product produced noticeably more active bath conditions which is a desired feature. There was no discernible difference in product quality by comparison to shop standards.

Summary of Tests One and Two

Heat Time

Actual times experienced for charge to melt, charge to tap and tap to tap respectively are provided for information purposes only since these are not considered appropriate measures of comparison.

Since there are rather frequent delays on almost all heats which are not necessarily of an unusual nature, but are certainly extraneous to the "normal" melting of a heat and in no way related to the materials themselves, it is appropriate to remove such recorded delays, thus providing a set of *adjusted* or net times. These are shown in Table IV.

	1st Test Run 85-Ton Furnace	2nd Test Run 135-Ton Furnace
Charge to Melt		
Control	3.84	3.94
R-N	3.95	4.21
Charge to Tap		
Control	4.86	5.34
R-N	4.94	5.50

Table IV — Adjusted Heat Times in Hours — Delays removed

R-N heats were slightly longer on the average than control heats, with respect to both charge to melt and charge to tap times. However, it is significant to note that the penalty is small in magnitude.

Tons Per Hour

If produced tonnages are equivalent, a small penalty in tons per hour would result from slightly longer heat times. Since there are always many factors determining what portion of the total metal coming out of the furnace results in good ingots, *total tons tapped* is a more appropriate measure than "good ingots" for a comparison of raw materials. R-N heats produced about the same total product as did the control heats. There is a small tons per hour difference, but it is not statistically significant. This is shown in Table V.

	1st Test Run 85-Ton Furnace	2nd Test Run 135-Ton Furnace
Control Heats	19.00	28.53
R-N Heats	18.33	27.72

Table V — Tons Per Hour — Total Metal Tapped — Adjusted Heat Times

Power Consumption

As was found in the first test run, the R-N heats required somewhat more power than did the control heats. The comparison based on K.W.H. per ton of total metal tapped is shown in Table VI.

	1st Test Run 85-Ton Furnace	2nd Test Run 135-Ton Furnace
Control Heats	525	448
R-N Heats	576	485

Table VI — K.W.H. per ton of Total Metal Tapped

Yields

A comparison of good ingot yields is not considered as meaningful a comparison as the gross product yield. The latter includes ingots, butts, skulls and pit scrap – all the metal produced from the materials used and which came out of the furnace. These figures are compared in Table VII.

	1st Test Run 85-Ton Furnace	2nd Test Run 135-Ton Furnace
Control Heats	94.13	96.20
R-N Heats	93.33	95.05

Table VII — Gross Product — Total Metal Tapped as % of Total Metallics

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The heavy bloom butts which the R-N briquettes replaced can be safely assumed to be 98.0% Fe. The R-N material melted averaged 95.30% Fe, a difference of 2.70%. On a 40% R-N replacement basis, *the R-N heats could be expected to produce 2.70% x 40% or 1.08% lower yields than the control heats.* Thus, there is some evidence of the possibility of a *slight* actual yield liability, over and above the difference in the iron content of the two materials.

Burnt Lime—Feed Ore—Carbon

The additional burnt lime consumed by the R-N heats in the amount of 8.43 pounds per ton tapped is indicated to be a significant difference. However, the fact that more burnt lime was *used* does not necessarily mean that more was *required.* The difference is statistically significant, but could be merely a reflection of how the heats were worked. Slag iron oxides (FeO) were higher on the R-N heats at tap, although they were lower at melt. This fact offers some evidence that the additional lime may have been needed, or at least provides the probable reason for such action by the melting crew. The objective was to charge sufficient additional carbon in the R-N heats to produce melt-in carbons equivalent to the control heats. Since the melt-in carbons were substantially the same, and since all heats were tapped for the same grade of steel, the carbon drop melt to tap would be substantially equivalent. This means the use of feed ore would be approximately the same. Actually, there was a small excess for the R-N heats, but not a significant amount, especially since the R-N heats actually experienced a four-point greater carbon drop from melt to tap.

Significant Items of Steel Analysis

Results show the phosphorous content of both control and R-N heats to be approximately the same. R-N heats had lower sulphur by five points, .030% compared to .035%. Total of incidental alloys (copper, nickel, chromium and molybdenum) was also substantially lower in the R-N heats, 0.262% compared to 0.339%.

Metallurgical Factors

Metallurgical examination disclosed no discernible differences in quality with respect to grain size, cleanliness, soundness, etc. Blooming Mill observation *produced definitely better ratings on surface quality during rolling on the R-N heats. This advantage is ascribed to the five points lower sulphur in a range which is rather critical surfacewise.*

Conclusions

The R-N briquette may be looked upon as a competitor of scrap and, in a way, it is. But in other ways it is not. Scrap is a by-product, the value of which fluctuates widely on a supply and demand basis. Likewise, its quality fluctuates widely and it may contain harmful residual elements. R-N briquettes, on the other hand, show the stable cost patterns associated with a manufactured product such as pig iron. The product is easier to handle, store and charge, and also offers the melter a charge material of uniform composition. For these reasons, the use of R-N briquettes to displace scrap, will undoubtedly prove more efficient and have a stabilizing effect on the price of scrap. This is sure to relieve steelmakers of the dangers resulting from excessive fluctuations in the price of scrap.

It is wrong, however, to look at high grade R-N briquettes as being just a competitor of scrap. Where a new installation is considered, there are indications that the combination of an R-N plant with electric furnaces would in many cases be more economic to operate and would involve less investment costs than a blast furnace-open hearth combination. Under such circumstances the R-N briquettes would be competing both with scrap and pig iron. A detailed discussion of the economics of this situation is beyond the scope of this article; it will suffice to say that it is believed the R-N Process can compete favorably under these circumstances.

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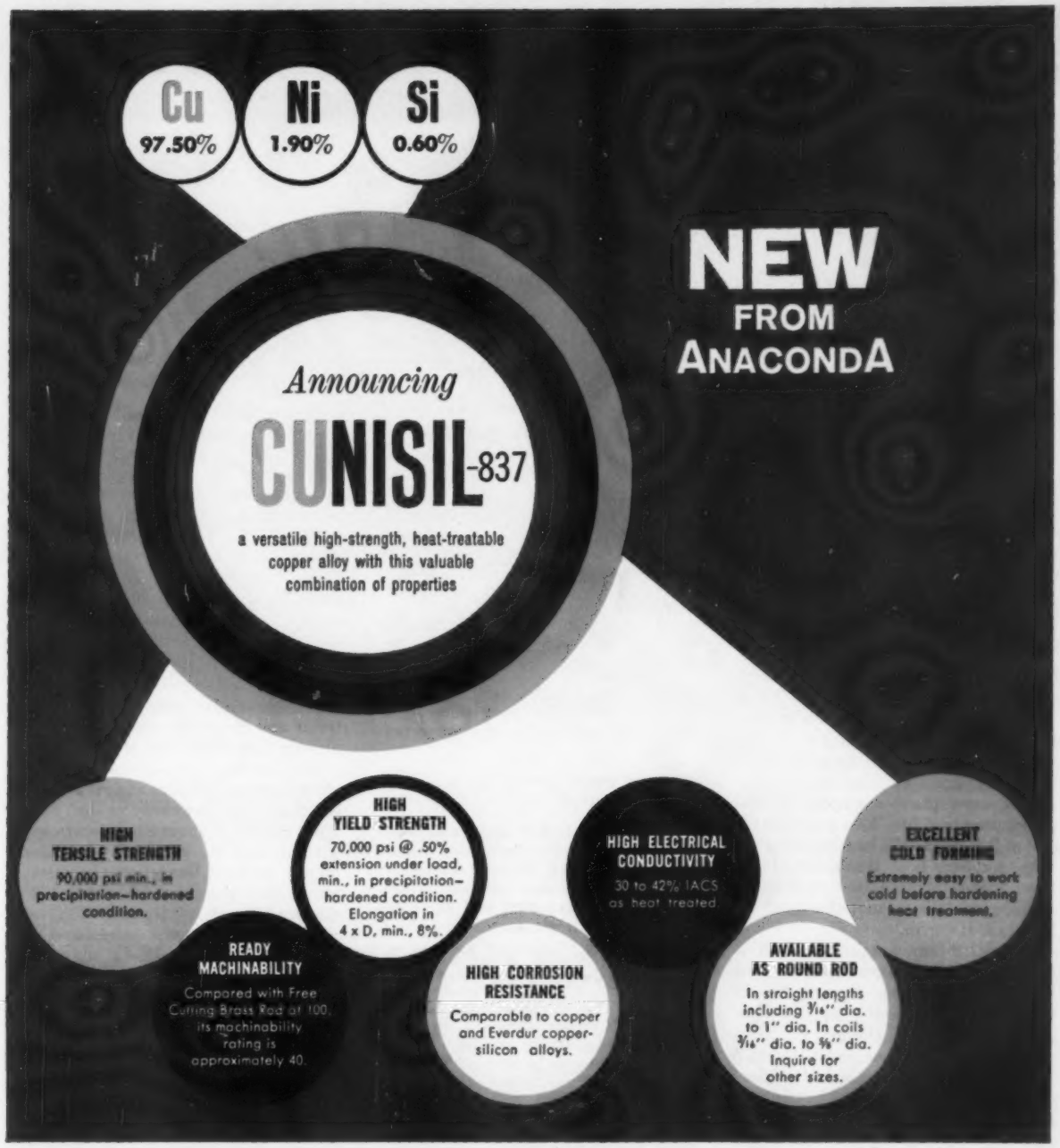
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Circle 1320 on Page 48-A

THE LITHIUM REACTOR

CURRENT INFORMATION ON LITHIUM CHEMISTRY AND METALLURGY

Magnesium-Lithium Alloys 25% Lighter than Magnesium

Promising New Alloys Save Weight Over Both Magnesium and Conventional Magnesium Alloys

In areas where lightness, strength, rigidity, formability and vibration dampening are important, Li-Mg alloys are being looked at very closely. These new alloys, containing small amounts of aluminum, equal or surpass the strength of more common Mg alloys.

Two considerations must be resolved before full commercial use of these alloys is established. First, the alloys over-age in two weeks from an as-cast tensile strength of 50,000-60,000 psi to a final strength of 25,000-30,000 psi. Also, the tensile strength is reduced rapidly at temperatures above 150°F, making insulation or cooling necessary where such temperatures are encountered. Both problems are now being worked on and are expected to be eliminated in the near future. Despite these limitations, however, many applications in a wide range of electrical and electronic components are already feasible for the alloys.

Most Li-Mg alloys are easier to machine than magnesium and sections of less than 1 inch are easily welded. They are workable at room temperature and when heated to 400°F are formable almost without limitation. In resonance, they compare favorably with standard Mg alloys. Up to 10% resonant frequency change is realized by substituting certain Mg-Li alloys for Mg counterparts, often reducing vibration stress where standard magnesium or aluminum parts in a structure have a resonant frequency within the critical range. This suggests extremely useful missile applications.

LITHIUM-CONTAINING SELF-FLUXING BRAZING ALLOYS EYED EXPECTANTLY

Aircraft Applications Prove High Heat Tolerance

Lithobraze 925, a self-fluxing silver brazing alloy containing .20% lithium, has been selected as the filler metal for brazing the 17–7PH stainless steel honeycomb sandwich panels of the B58 Hustler pictured *(below right)*. This lithium-containing self-fluxing alloy is ideal for the B58 application because *it withstands intermittent temperatures up to 800°F* from the exhaust stream and engine. In addition, it is not subject to crevice corrosion, requires no flux, brazes at lower temperatures – saving time, reducing atmosphere consumption and prolonging tool life. Also important is that at this material's brazing temperature, solution heat treatment of the base metal is also accomplished! Lithobraze 925 is manufactured by Handy & Harman.

Other lithium-containing self-fluxing brazing alloys have been produced by Handy & Harman to meet the requirements of specific applications. According to Mr. Donald C. Herrschaft, Assistant Manager of Handy & Harman's Brazing Products Division, the future for this type of brazing alloy looks bright. Numerous industrial uses are suggested by the heat resistant properties the alloys display as well as the ease of their use. Mr. Herrschaft is confident that as private industry realizes their value, sufficient demand will make possible volume production and prices more nearly competitive with those of alloys which require fluxing agents.

For further information call or write – Handy & Harman, 82 Fulton Street, New York 38, N. Y. or Lithium Corporation of America.

LITHIUM IN BRIEF

New developments involving lithium are constantly appearing in the literature. Each month some will be reported here. For further information, write our Technical Service Department in Minneapolis.

A new magnetic material can be prepared by heating ferric and chromic oxide hydrate with lithium carbonate. (1983).

Recently demonstrated fuel cell involves electrodes of lithium-nickel double oxide with good semiconducting properties. (1954).

A recent report reviews the properties of lithium carbide. (1917).

A recent U.S. Patent describes a wrought-aluminum base alloy containing lithium and copper as well as small amounts of manganese, cadmium and magnesium. Solution heat treatment and aging for greater strength are described. (1789).

Silver base brazing alloys containing lithium are discussed in a recent article. (1593).

An A.E.C. report discusses the preparation of high purity yttrium by reduction of the chloride by lithium. Yield and analysis of yttrium are included. (1647).

Newest Air Force bomber – the B58 – uses a brazing alloy containing lithium.

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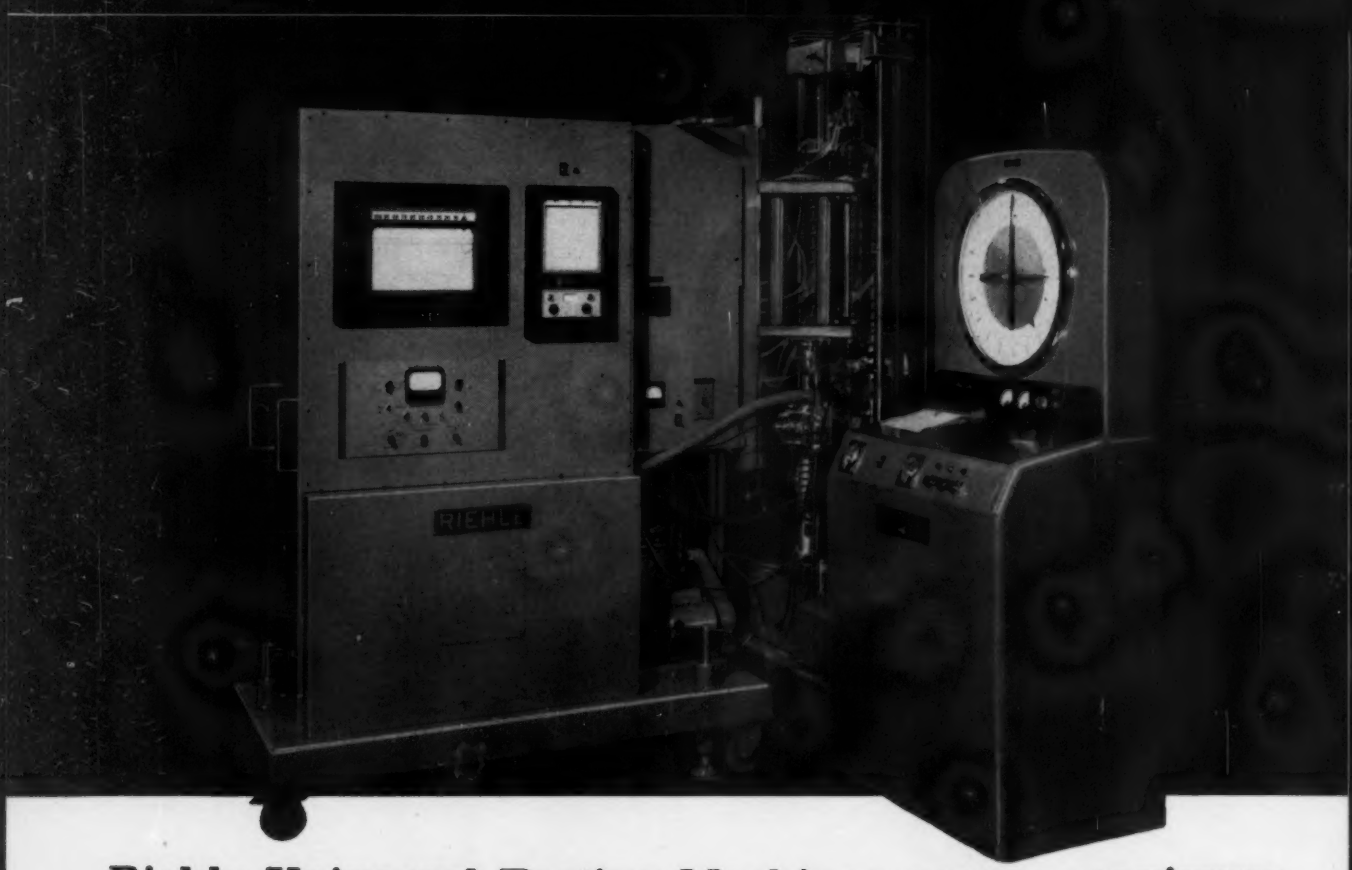

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Nonferrous Metals

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Aluminum foil insulation, especially for use between zero and 150°F., is now being made in rolls, 36-in. wide and of three types: *(a)* Reflective foil affixed with asphalt to paper on one side only, *(b)* similar foil with asphalt-paper lamination in both sides, and *(c)* a foil similar to the first but perforated so as to pass vapor. Types *(a)* and *(b)* serve as a vapor barrier as well as a reflector of heat waves. *Kaiser Aluminum & Chemical Sales, Inc.*

For further information circle No. 1020 on literature request card, p. 48A and B.

Tantalum-Tungsten Sheet

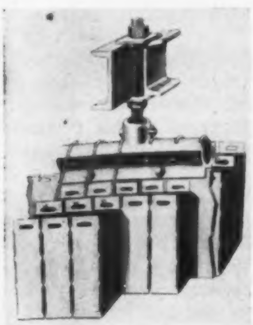
90-10 Ta-W alloy in sheet and wire form, originating from arc-melted ingots, is now available for uses demanding exceptional strength and ductility at high temperature. Toughness extends to low temperatures, as well. For example, the standard V-notch Charpy specimen absorbs a blow of 220 ft.-lb. without fracture. Cold rolled sheet, 0.030 in. thick, withstands 12,500 psi. for 26 hr. at 3000°F.; 4000 psi. for 4 hr. at 4300°F. 0.009-in. wire drawn from 0.1-in. annealed rod (99% reduction) has tensile strength at 70°F. of 210,000 psi. *National Research Corp.*

For further information circle No. 1021 on literature request card, p. 48A and B.

Heat & Corrosion Resistant Materials

Basic Refractory Roofs

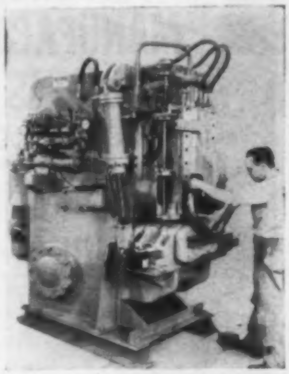
In keeping with the trend toward "all-basic" furnace construction and especially basic roofs for openhearth furnaces (suitable for faster production at higher temperatures and with oxygen lancing) *Refractories Division of H. K. Porter Co.* has devised a new suspension for roof and end-wall wherein the brick are individually "wrapped" in metal rather than being fitted to pre-shaped cases. The following unique advantages are claimed: *(a)* A built-in air cleaning and cooling system covering the entire roof, *(b)* simple tab supports for the brick, and *(c)* notched tie plates that slip into place and are anchored to pipes for support. These features provide proper allowance for expansion throughout the entire system.



For further information circle No. 1022 on literature request card, p. 48A and B.

Tube Bender

A new 30-ton press has many new features, particularly the generous clearance for the work on all sides of the dies provided by offsetting the ram and wing-die holders, and mounting the wing-die cushion cylinders at the side, thus giving a broad range of bends to different angles and in more than one plane in a single tooling and on one pass through the press. It can handle steel pipe up to 3 in. O.D. and 0.125 in. wall, and laminated tubing up to 2½ in. diameter. Automatic return to original position after making a given number of bends is responsible for high production (800 bends per hr.). The 40-hp hydraulic system is contained in the base. *Pines Engineering Co., Inc.*



For further information circle No. 1023 on literature request card, p. 48A and B.

Filler Snake for Stretch Forming

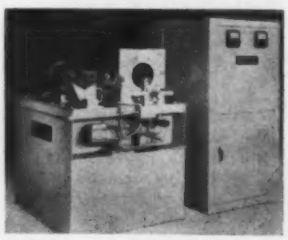
Filler "snakes" are ordinarily an assembly of thin blocks. In order that these may reach the minimum size and maximum conformity to any curved surface, the HOBE (HOneycomb Before Expansion) snake shown in the workman's left hand is a stack of aluminum foil 0.005 in. thick. Size and shape can be varied to suit the job. The workman holds in his right hand a bent shape with angle cross section made in this way. Cost is low and durability extends to several hundred extrusions. *Hexcel Products.*

For further information circle No. 1024 on literature request card, p. 48A and B.

Industrial Heating

Low-Frequency Induction Heater

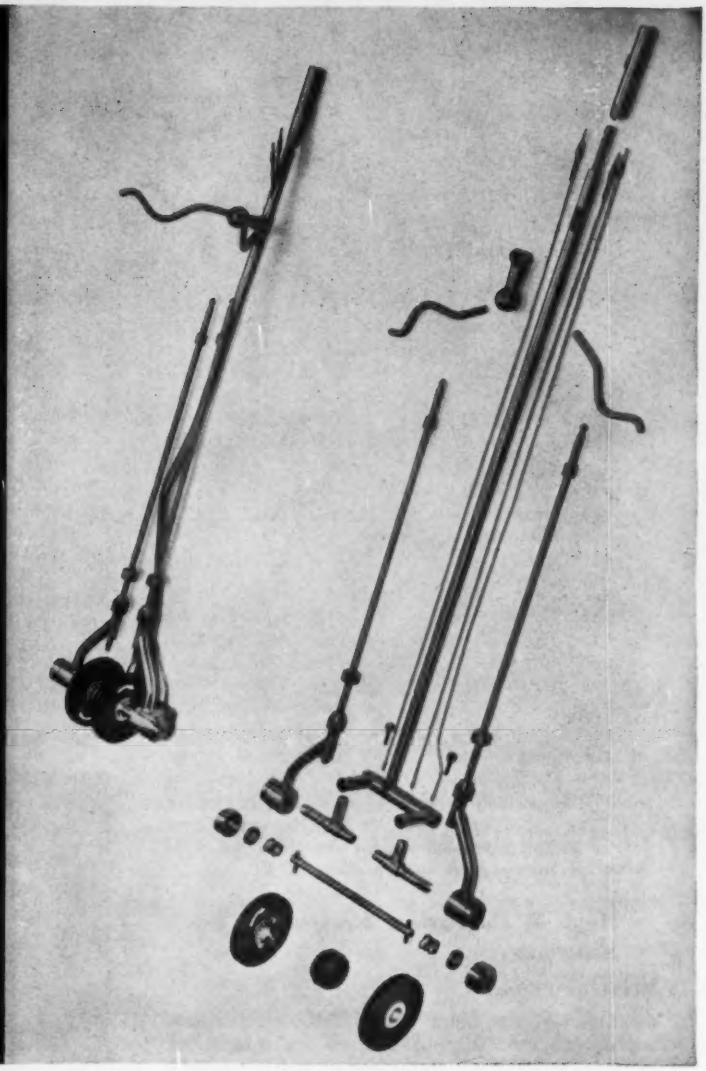
Circular parts like rollers, wheels, disks in diameter from 6 to 14 in. can be heat treated under program control in the semi-automatic low-frequency equipment illustrated. It takes power from a conventional 60-cycle lighting circuit or from a 180-cycle frequency converter. It indexes parts automatically, places them in the heating coil for the required time, pushes the part through to the quench, meanwhile the fixture returns to the loading station for another part. Advantages are rapid production, practically no scale or decarburization, minimum residual stresses. *Ajax Magnethermic Corp.*



Circle No. 1025, p. 48A

HERE'S HOW STILL ANOTHER MANUFACTURER JOINS STAINLESS STEEL TUBING:

He uses Handy & Harman's BRAZE 630



He's one of many manufacturers and fabricators who have found—to their lasting satisfaction—that Handy & Harman silver alloy brazing is the final answer to stainless steel joining problems.

Super-Donic Manufacturing Company, Atlanta, Georgia, manufactures "Dual Arm Transmissions" for the dental industry. Most everybody has—at one time or another—seen and/or felt this unit in operation.

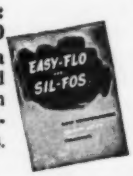
It is fabricated of small diameter 304 and 316 stainless steel tubing and, in its assembled form, consists of some 17 separate brazed joints. Joints must be strong, corrosion resistant and neat-appearing.

Each of the 17 joints is hand-torch brazed with Handy & Harman BRAZE 630 wire and HANDY FLUX TYPE B-1. There's no question that this is a unique application. There's no question, either, that the application is stainless steel. The ease and economy with which this manufacturer solves his problems can be just as readily applied to *your* stainless steel joining problems.

Strength, production speed, electrical and thermal conductivity, gas and liquid tightness and low cost are *natural* benefits of silver alloy brazing. We think it worth your while to learn more about this remarkable metal-joining method—we'll be glad to send you any information you ask for. Handy & Harman, 82 Fulton St., New York 38, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits... includes details on alloys, heating methods, joint design and production techniques. Write for your copy.



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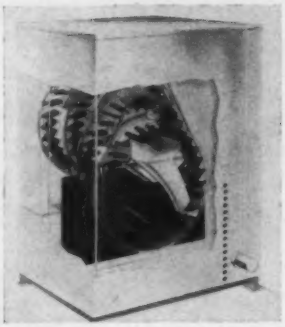
San Francisco, Calif.
Montreal, Canada
Toronto, Canada

Circle 1324 on Page 48-A

Ultrasonic Tumbler



The "AutoSonex" is intended to receive metal parts as fast as they come from grinders or screw machines. It has four wheels with cubicles evenly spaced around the rim. Transfer from one to the other is automatic. The first wheel immerses the parts in a degreasing solution powered by ultrasonics, the second is for rinsing, the third for draining and the final wheel is in an isolated solvent chamber. Solutions can be selected to conform to the requirements. The rotating wheel admirably drains all blind holes and liquid traps. *Metalclean Equipment Co.*

For further information circle No. 1026 on literature request card, p. 48A and B.

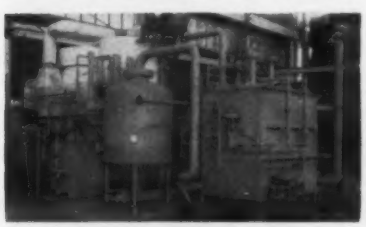
Inexpensive Ultrasonic Cleaner

Touted as the only cleaner selling complete for less than $100, "DiSONtegrator System Forty" has a tank with half-gallon capacity made of deep drawn stainless sheet, and will accept work up to 6½ in. in major dimension. The 40-watt generator is plugged into any 110-volt current of 50 to 60 cycles and delivers 90,000 impulses per sec. The cabinet has only one main switch and one knob to regulate the activity. *Ultrasonic Industries, Inc.*

For further information circle No. 1027 on literature request card, p. 48A and B.

Hydrogen Generator

The equipment shown is suitable for steel mills or other production departments requiring much hydrogen. It re-forms natural gas and purifies it



at a cost of about 70¢ per 1000 cu. ft., considerably less than the cost of electrolyzing water. Each generator has a capacity of 10,000 cu. ft. per hr. A tank for storing gas at high pressure is also included. *Surface Combustion*

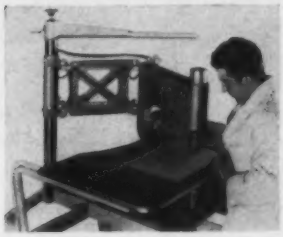
For further information circle No. 1028 on literature request card, p. 48A and B.

Silver Solder Rings

Silver solder rings of precise diameters, thickness and overlap are available from *Alloys Unlimited, Inc.* They contain exactly the correct amount of a specific soldering alloy and eliminate scrap, waste and inventory. Packed on cardboard or metal mandrels to prevent tangling.

Circle No. 1029, p. 48A and B.

Torch Cutting Machine



Milo Mfg. Co. has a simplified cutting machine using oxygen and any fuel gas. The cutting torch and tracer are mounted on a U-shaped arm, reaching below and above a guide table; the shape corresponds to a full-size templet or drawing. Four methods of operation: *(a)* Cutting to templet, wherein a magnetic guide roller follows the profile; *(b)* cutting direct from a drawing, wherein a pin is directed by hand; *(c)* straight cuts wherein the guide wheel runs along a parallel guide; and *(d)* circular cutting wherein the pivot is fixed magnetically to the guide table and a compass beam is attached to the wheel head. Cuts can be up to 75 in. long, 29 in. wide, and in steel plate up to 4 in. thick.

For further information circle No. 1030 on literature request card, p. 48A and B.

Ultrasonic Welder

The rotary-tip foil welder is designed for the electrical and packaging industries. Foil as thin as 0.00025 in. and as thick as 0.006 in. can be joined to itself or to a metallic foundation or connection. Ultrasonic energy, generating practically no heat, is capable of joining

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Pull tensile tests wherever you may be—in the shop or in the field, in the lab or on the line. Tests flat or round specimens, cast coupons or weld samples. Two simple, compact sizes. Light enough to be carried by two men; rugged enough to stand up under constant moving. Can be mounted on wall or bench according to space limitations.

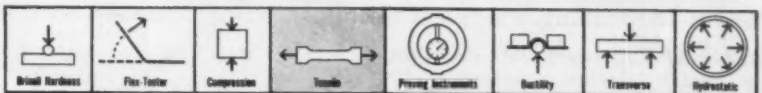
Easily adjustable for specimens up to 2" wide, 12" long. Interchangeable wedge-type jaws readily inserted and adjusted. Load applied hydraulically by manual pump. Capacities up to 40,000 lbs. Cylinder stroke is 2½". Gage is 8½" OD, has maximum indicating hand.

Distributors in most major metalworking areas

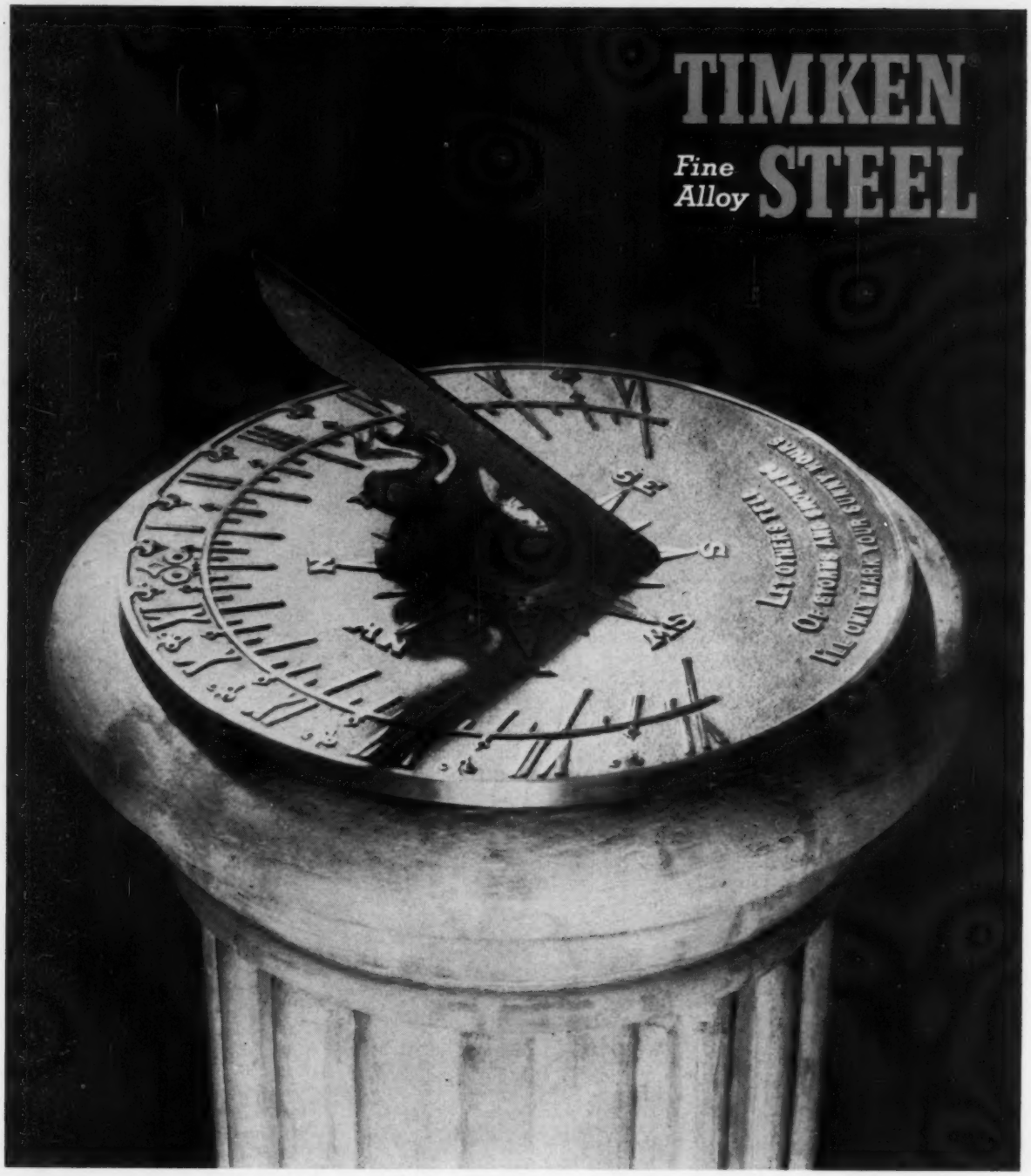
Write or call Steel City if you have any testing problem

Steel City Testing Machines Inc

8811 Lyndon Ave., Detroit 38, Mich.



Circle 1325 on Page 48-A



SUN TIME or any time is the time to order your Timken® 52100 steel tubing. It will be shipped within 24 hours of the time we receive your order. We carry 101 sizes in stock—from 1″ to 10½″ O.D., in a wide range of wall thicknesses, to make this speedy service possible for less than mill quantities. And remember, 90% of the structural parts that can be made from seamless tubing can be made from either of the two Timken grades—52100 and 4620. The same service is available on 50 sizes of 4620 tubing. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. *Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.*

See us at the Atomic Exposition, New York Coliseum, April 4-7, Booth 228

Circle 1326 on Page 48-A

slightly oxidized aluminum and high-conductivity copper. The equipment, once set, maintains the correct welding angle, speed and pressure. Welding horn and power generator are integrated into a single housing. *Vibro-Ceramics Division of Gulton Industries, Inc.*

For further information circle No. 1031 on literature request card, p. 48A and B.

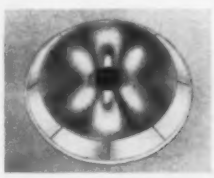
Inspection and Control

Testing Machine Grips

About the only things that go wrong with a good testing machine, even in a busy inspection department, are the grips. Rather than go to the expense of new wedge blocks, inserts called "Griff Grips" are ready replacements. There are three standard 8000-lb., 10,000-lb. and 20,000-lb. holders. They have 100% gripping surface, made of hard toolsteel, toughened to resist shock. *Griff Machine Products Co.*

For further information circle No. 1032 on literature request card, p. 48A and B.

Visual Stress Indicator

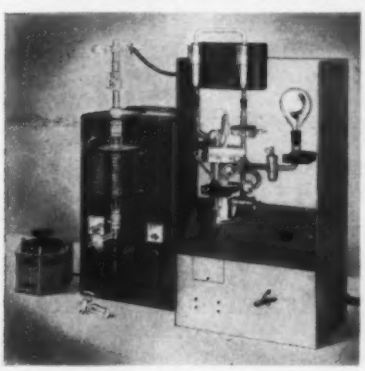


Directions of the principal stress or strain can be spotted instantly and visually by the "B-L-H Strainline Photoelastic Strain Compass" attached to the test piece's surface. No external instrumentation or connections are required, nor any electrical or mechanical magnifiers. This photoelastic device with its built-in polarizers can be read easily in natural or artificial light. A similar instrument in a rectangular frame will produce visible interference fringes whose displacement is proportional to the strain, however, the *direction* of principal strain must be known and the gage attached in that direction. *Baldwin-Lima-Hamilton, Electronics Instrumentation Div.*

For further information circle No. 1033 on literature request card, p. 48A and B.

Hydrogen Analyzer

New "Leco" hydrogen analyzer is compact and speedy; it takes 3 to 10 min. to make an extraction. Outgassing of a crucible is avoided by using an inert, blank-free susceptor. Successive samples can be loaded, inserted, analyzed and removed without breaking the vacuum. Its speed and accuracy will encourage its use to check incoming metals as well as to verify that no hydrogen has been absorbed during processing. *Laboratory Equipment Corp.*



For further information circle No. 1034 on literature request card, p. 48A and B.

Versatile Recorder

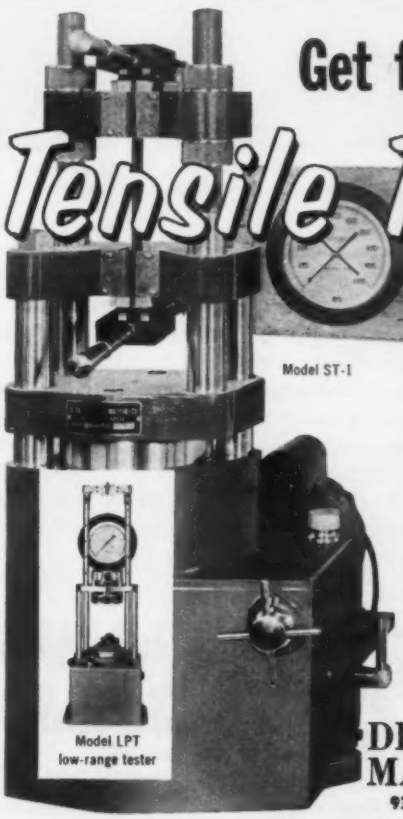
The Bristol Co. is now offering a new "Dynamaster" potentiometer recorder, a wide-strip instrument for measuring such things as pressure, temperature, motion, flow, density, pH, and electric current. Any one of four inputs may be selected in five spans from 0 to 2 (low) to 0 to 50 (high). Chart drive has several speeds.

For further information circle No. 1035 on literature request card, p. 48A and B.

Universal Indicator

The Foxboro Co. has produced a group of indicating transmitters called "Model 45 Series". Using 20-psi. air it measures the following: Pressure: zero to 80,000 psi.; temperature: 450 to 1000° F.; flow: zero to 400 in. water differential pressure; liquid level: zero to 20 in. water; dew point −50 to +165° F. The instrument is almost insensible to normal changes in ambient temperature; a 50° F. change introduces an error of 0.5%.

Circle No. 1036 on request card.



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hydraulically

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DETROIT TESTING MACHINE COMPANY

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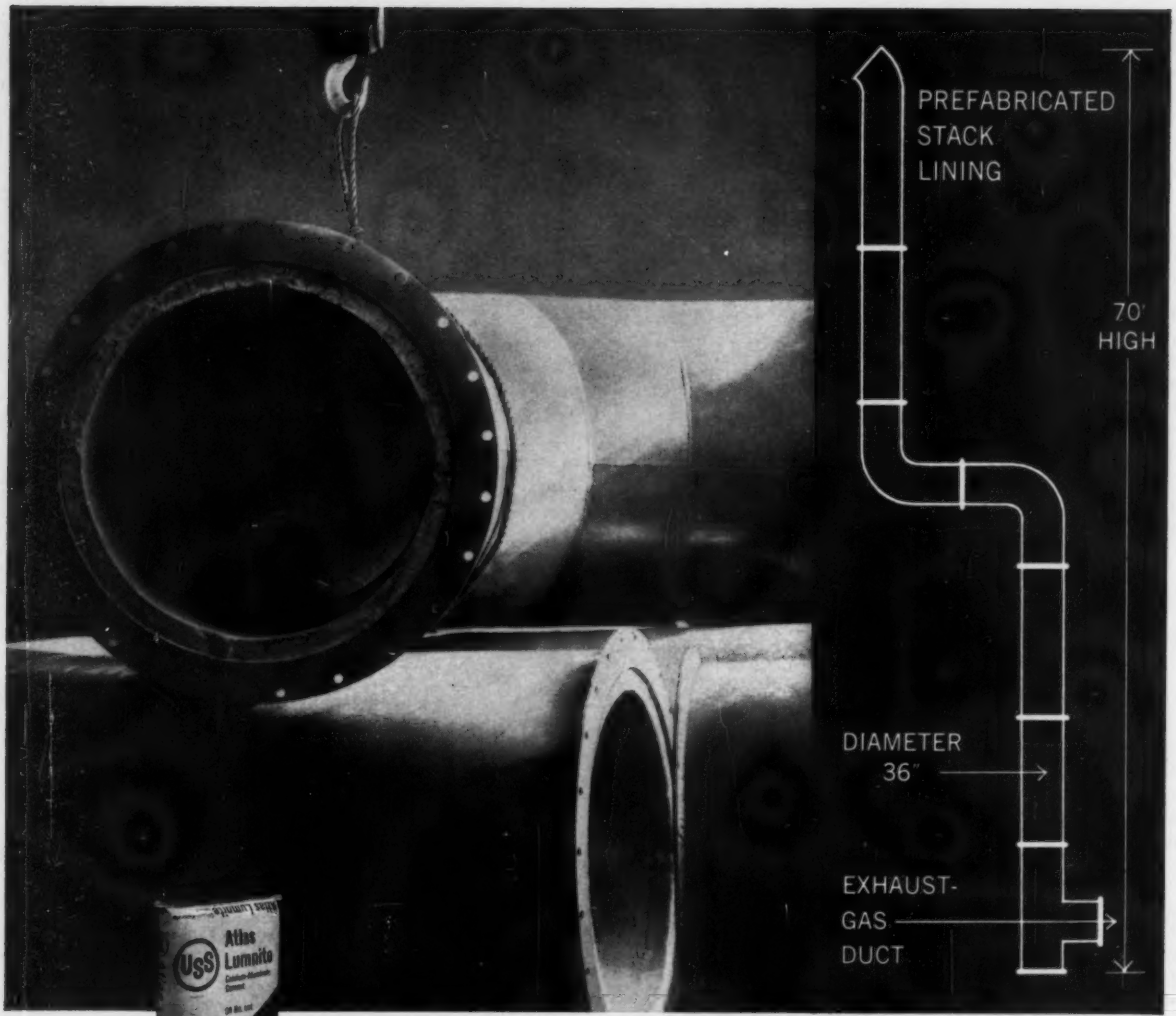
Circle 1327 on Page 48-A



Castable-lined prefab sections of waste-gas ducts and stacks for pit annealers at United States Steel's Homestead (Pa.) Works. **Contractor:** Amsler Morton Company, Pittsburgh, Pa.

Castable lining in prefab stacks reduces costs

When unusual stack and duct layouts are necessary, prefab elbows, tees, dog-legs and straights can be pre-lined with a refractory insulating concrete at considerable savings. Using a castable refractory, bonded with LUMNITE calcium-aluminate cement, monolithic linings can be cast in place without anchors or reinforcing mesh. Since the concrete will reach service strength in 24 hours, early release and re-use of forms are possible, speeding the job. Compared to cutting and fitting small refractory units, there is less material loss. Cluttered job sites and scaffolding are eliminated. And casting indoors means no delays due to weather. Leading manufacturers of refractories offer castables bonded with LUMNITE cement for a variety of installations in metalworking. Castables are packaged mixtures, ready to use. Simply add water, mix and place. For details, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

L-202

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Universal Atlas Cement
Division of
United States Steel

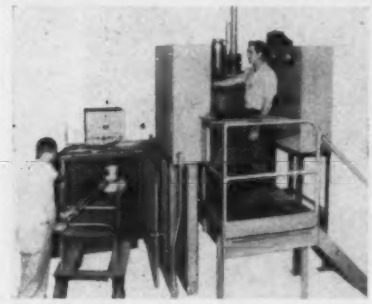
Offices: Albany · Birmingham · Boston · Chicago · Dayton · Kansas City · Milwaukee · Minneapolis · New York · Philadelphia · Pittsburgh · St. Louis · Waco

Circle 1328 on Page 48-A

Production

Vacuum Melter and Caster

Semicontinuous operation is the feature of units of capacity ranging from 17 to 100 lb., one of which is illustrated. It has one chamber (at right) for melting and one for molds

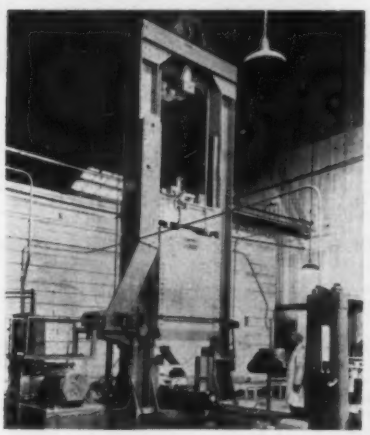


(at left) connected by a lock – essentially a sliding door. Stock and alloy are added through a separate port; other ports in the melting chamber give access to thermocouples or sampling buckets. Several molds can be fitted on a turntable carriage and poured from one melt. Centrifugal casting devices may also be incorporated. *F. J. Stokes Corp.*

For further information circle No. 1037 on literature request card, p. 48A and B.

Casting Conditioning

A special-purpose hydraulic press for casting conditioning has been announced by *Elmes Engineering Div., American Steel Foundries.* The machine is used to build up initial capac-



ity in a draft gear. The draft gear fits into a pocket in the sill of a railroad car frame, and acts as a shock absorber. By dropping a 27,000-lb. weight from varying, successively increasing heights, this unit conditions the rough-cast mating surfaces of the follower wedge, the friction shoes, and the draft gear housing so as to form mat-

For almost every hardness testing requirement

There's a Wilson "Rockwell" instrument to do the job

Wilson "Rockwell" Hardness Testers can help make your products better, stronger, longer lasting. They give reliable results on the production line, in laboratories, in tool rooms, and in inspection departments. They're as easy to use as a center punch, as durable as a machine tool, as sensitive and accurate as a precision balance. That's why Wilson "Rockwell" is recognized as the world's standard of hardness testing accuracy.

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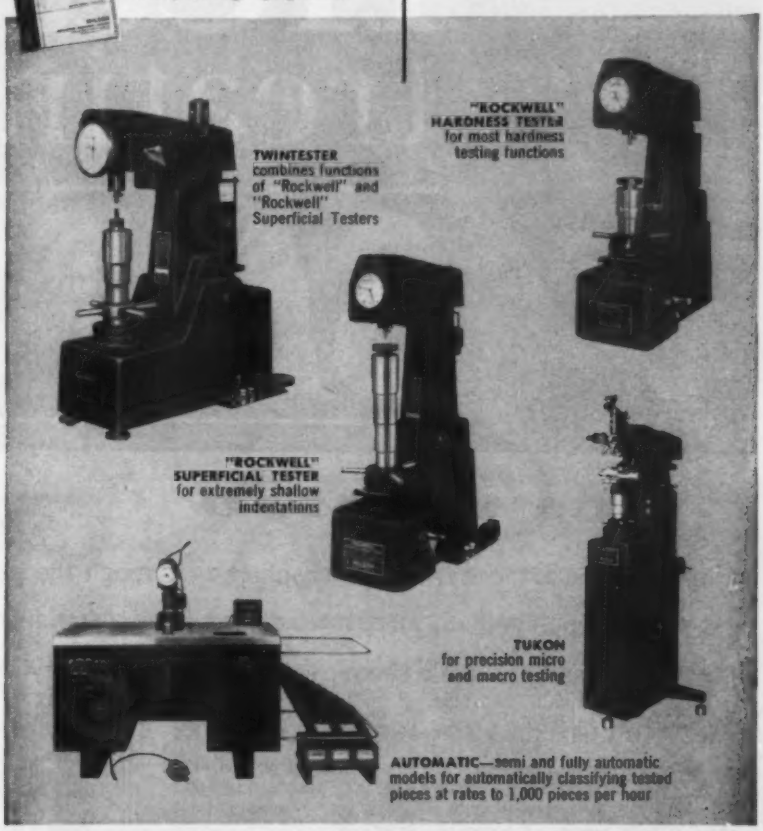
A perfect diamond penetrator is essential to accurate testing. Only flawless diamonds are used with Wilson "Brale" penetrators. Each diamond is cut to an exact shape. Microscopic inspection and a comparator check of each diamond—one by one—assure you of accurate hardness testing every time.

Write for Catalog RT-58. It gives complete details on the full line of Wilson hardness testing equipment.


TWINTESTER
combines functions of "Rockwell" and "Rockwell" Superficial Testers
"ROCKWELL" HARDNESS TESTER
for most hardness testing functions
"ROCKWELL" SUPERFICIAL TESTER
for extremely shallow indentations
TUKON
for precision micro and macro testing
AUTOMATIC—semi and fully automatic models for automatically classifying tested pieces at rates to 1,000 pieces per hour

WILSON "ROCKWELL" HARDNESS TESTERS

ACCO

Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
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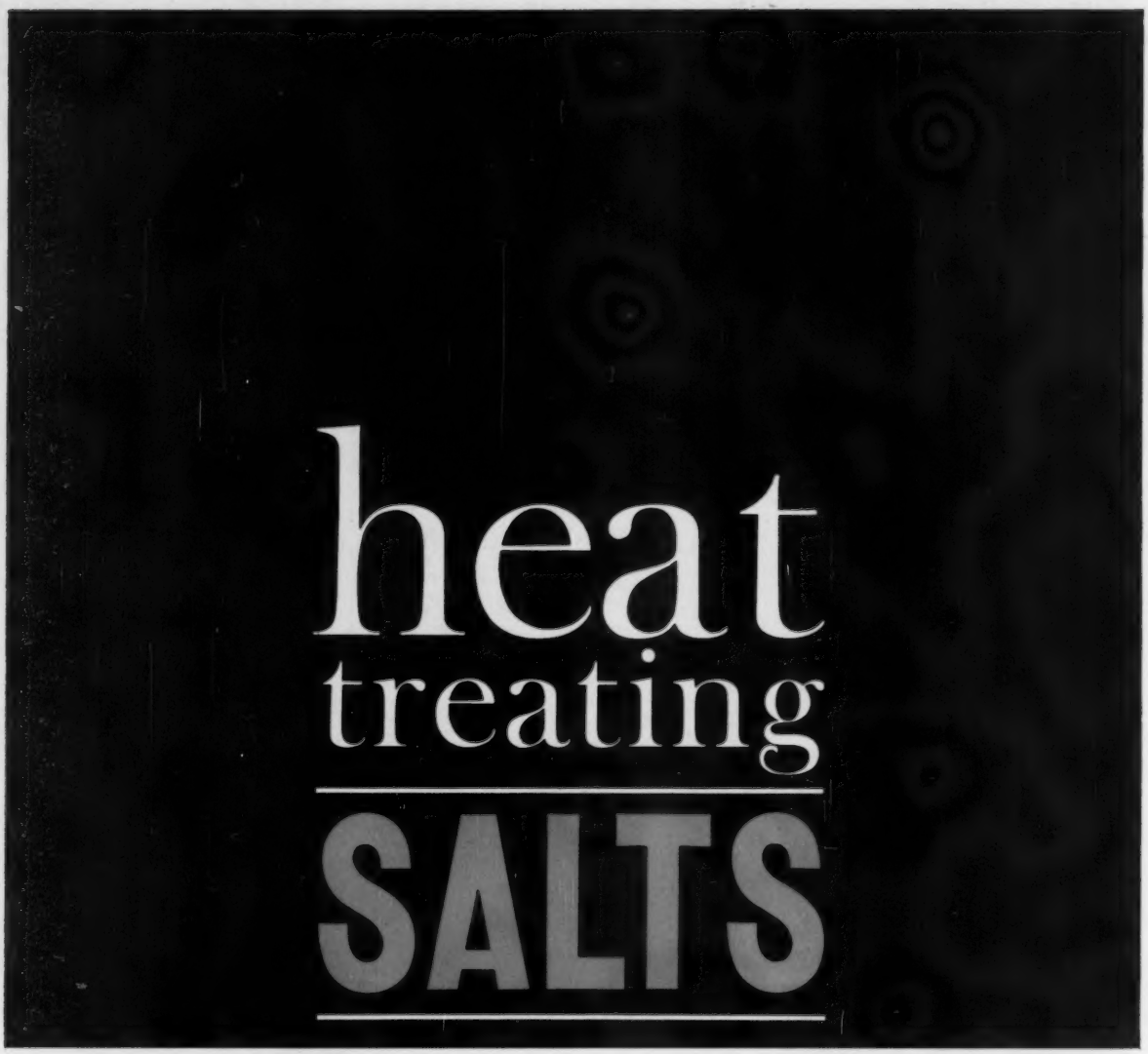
Circle 1329 on Page 48-A



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Position_____

Circle 1330 on Page 48-A

A
AMERICAN
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A MAJOR BREAK-THROUGH IN MODERN RESEARCH TOOLS

FEATURING A MACHINE THAT FINDS INFORMATION

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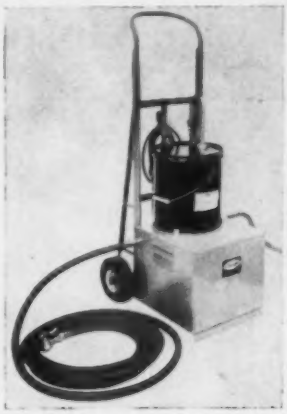
Metals Park,
Dept. P4
NOVELTY, OHIO

ing coined surfaces. The weight is dropped in free fall from a minimum distance of 2 in. to a maximum of 36 in. with ten intermediate steps.

For further information circle No. 1038 on literature request card, p. 48A and B.

Portable Dust Suppressor

Four models (two manually controlled and two automatically) of dust suppressors operate by controlled wetting of the raw materials at mullers, shake-outs, mixers, or receiving bins in foundries and other plants. The hand truck shown is attached to the plant's water supply (40 psi.) and delivers an emulsion through hose and nozzle at left. Minute amounts — as little as 1 part per 1000 — of surface-active compound or dust suppressor are added to the spray. The standard unit delivers 6 gal. per min. *Johnson-March Corp.*



For further information circle No. 1039.

Cutter for Wire Cloth and Expanded Metal

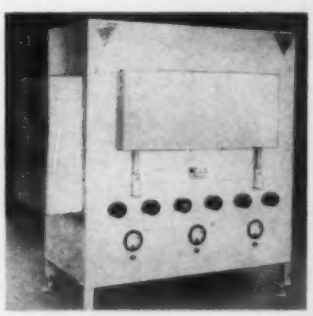
Wire cloth and expanded metal have always been hard to cut with conventional tools. Shears distort the work badly in sizes larger than 0.06 in.; friction saws require a rigid hold-down and leave very sharp burrs; flame cutting is slow and often leaves slag behind. An Arcair Process torch is the answer. It strikes an arc from an inexpensive electrode and a jet of compressed air blows the metal away as fast as it melts. Cutting speeds are up to 48 in. per min., and cuts are clean and smooth. *Arcair Co.*

For further information circle No. 1040 on literature request card, p. 48A and B.

Parts, Forms, Shapes

Powder Metallurgy

Calcining of ceramic or metal powders at temperatures up to 2500° F. is done in "Model RT-472" furnace made by *Pereny Equipment Co.* The powders work their way gradually along a rotating mullite tube at the rate of 5 to 20 lb. per hr. The front feet of the furnace can be screwed up to adjust the slope of the calcining tube. Heating elements are silicon carbide; power input (30 kw.) is regulated in three zones.



For further information circle No. 1041 on literature request card, p. 48A and B.

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We can now make, and deliver in every shipment, the exact type of "Malleabrasive" shot or grit that will do your particular job best . . . and at lowest cost to you.

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THE GLOBE STEEL ABRASIVE CO.
Mansfield, Ohio

Sold by many leading distributors of foundry supplies from coast to coast.
Circle 1331 on Page 48-A

MALLEABRASIVE

Polimet

A NEW NAME IN METALLOGRAPHIC POLISHERS

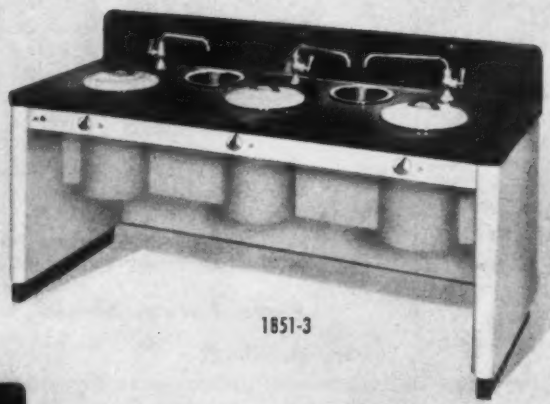
- VARIABLE SPEED—100-1200 r.p.m.
- QUIET OPERATION
- VIBRATION FREE
- EASY CONTROL
- HIGH TORQUE—½ h.p.
- AVAILABLE IN 1, 2 or 3 UNIT TABLES
- INTERCHANGEABLE BALANCED WHEELS
- VITREOUS FINISHED, EASY TO CLEAN BOWL

1851-1

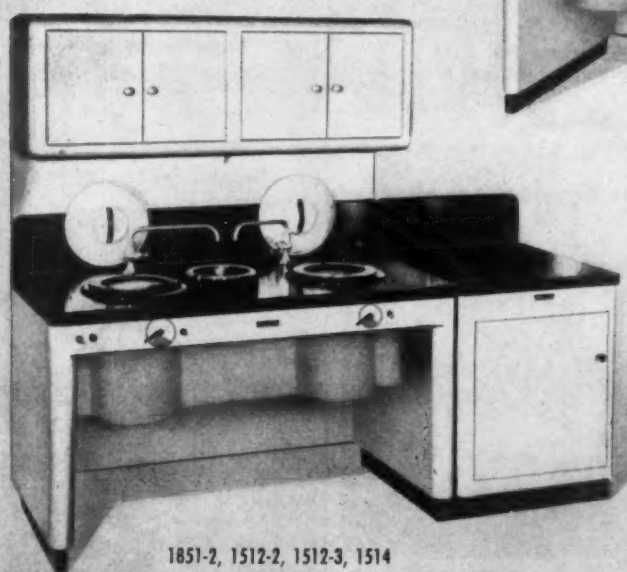
1851-2

With infinitely variable speed over a wide range it is possible for the operator to select the exact speed desired for the particular sample at hand. The complete speed range is controlled by turning a knob. No cranking is required to change speed, no belts, pulleys or mechanical clutches are used, eliminating the source of most vibration present in other variable speed polishers. The electronic control is accomplished through the use of only one vacuum tube and the complete electronic circuit is mounted on a 4" x 4" panel easily accessible on the outside of the motor.

The 1851 Polimet series is furnished in the Buehler steel polishing tables, finished in silver gray hammertone. The top and edges of the table are black formica. One, two, or three unit tables are available.



1851-3



1851-2, 1512-2, 1512-3, 1514

Buehler Ltd.

METALLURGICAL APPARATUS

2120 GREENWOOD ST.,
EVANSTON, ILLINOIS, U.S.A.

Circle 1332 on Page 48-A

Tool Steel Topics

BETH EHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Bake Tools After Plating

There are three reasons why tools are electroplated with chromium or nickel: (1) salvage, by regaining worn dimensions, or correcting mechanical errors (2) decoration (3) to resist wear or metal pickup.

Although electroplating of hardened tools is relatively simple, it can be hazardous if the plating is not followed by baking (tempering). During deposition of the plated metal, a considerable amount of hydrogen also is deposited on the tool. Some of this hydrogen diffuses into the tool. This causes extreme brittleness, so that if the tool is used immediately after plating, breakage in service may occur.

To avoid such an occurrence, bake the tool at 300-400F for at least four hours, to restore its original ductility. Baking should begin as soon as possible after plating. Grinding should never be done on the steel itself prior to baking. If baking is omitted, the tool will gradually recover its ductility at room temperature in from two to three weeks. It will be subject to breakage if used before the recovery has been completed.

Inserts of Brake Die Tool Steel form runners for oven wrappers

The sheet-steel part above is an oven "wrapper" for a gas range, produced by Caloric Appliance Corp., Topton, Pa. The wrapper has deep side-member runners on opposite sides. These were formed by inserts of Bethlehem Brake Die in the tool steel forming die at the right of the photograph.

Caloric's engineers reported fine results with Brake Die because of its durability. It also proved economical, as it saved time during machining. Used in duplicate sets of three, the inserts formed 22-gage steel to the tune of some 4,000 pieces before polishing became necessary.

Bethlehem Brake Die is ideal for intricate bending and forming applications because of its fine wear resistance, high toughness, and exceptional resistance to impact. It saves money, because it comes in the heat-treated condition, ready for machining without further hardening. We not only quench and temper Brake Die to develop its superior properties—we also straighten it mechanically. This is followed by a stress-relief-anneal, then gag straightening.

Give Brake Die a trial. But don't baby it—choose a tough job. The nearest Bethlehem tool steel distributor will be pleased to work with you.

Because of its high vanadium content, Bethlehem Cromo-High V is ideal for die casting aluminum- and magnesium-base alloys in the 1200F-1300F range.

Cromo-High V has outstanding machinability because it comes in the annealed condition (Brinell 207). It has excellent resistance to the formation of a fine network pattern of heat checking. In heat-treatment, it develops the uniform hardness needed to resist wash and erosion.

Circle 1333 on Page 48-A

Free Sample Tube

Industry's NEWEST Production TOOL

MOLYKOTE® G LUBRICANT

- ALMOST 100% SAFETY AGAINST GALLING AND SEIZING WITH ALL BEARING METAL COMBINATIONS
- ELIMINATES STICK-SLIP, METAL PICK-UP AND DISTORTION IN PRESS FITTING
- REDUCES WEAR-IN TIME AND DAMAGE IN NEW OR REBUILT MACHINERY
- THE HIGHER THE LOADS, THE GREATER THE MARGIN OF SUPERIORITY OF MOLYKOTE G

Write for your free sample of MOLYKOTE G LUBRICANT today. We will also send you a copy of our new Bulletin 126 which gives complete details. THE ALPHA-MOLYKOTE CORPORATION, 65 Harvard Avenue, Stamford, Conn. Phone Fireside 8-3774. Plants in Stamford, Conn., Munich, Germany and Strasbourg, France.

THE ALPHA-MOLYKOTE CORP.
65 Harvard Ave., Stamford, Conn.
Please send me a free sample of your MOLYKOTE G Lubricant.
NAME_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

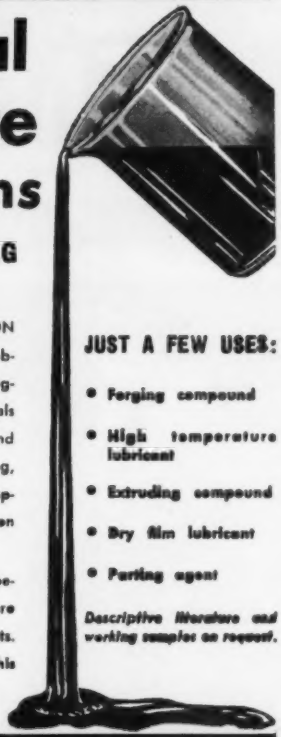
Circle 1334 on Page 48-A

Colloidal Graphite dispersions

FOR THE METAL WORKING INDUSTRY

GRAPHITE PRODUCTS CORPORATION manufactures quality metal working lubricants. Lubricants for titanium, magnesium, aluminum and the new metals as well as steel, stainless steel, and alloys. Lubricants for forging, extruding, drawing, and other metal working operations. Lubricants you can count on to do the job.

A qualified staff is available for specialized development service. You are invited to submit your requirements. There is of course no charge for this service.



JUST A FEW USES:

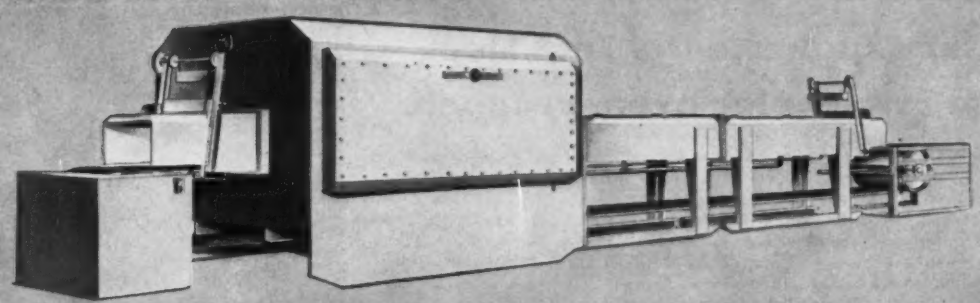
- Forging compound
- High temperature lubricant
- Extruding compound
- Dry film lubricant
- Parting agent

Descriptive literature and working samples on request.

GRAPHITE PRODUCTS CORPORATION
BROOKFIELD, OHIO

Circle 1335 on Page 48-A

HEAT from General Electric



for copper brazing, silver brazing, sintering, bright annealing

Mesh-belt Furnaces from General Electric are specially designed for low-cost, high-volume production. They can be installed in a continuous production line, accepting parts ready for heat processing and delivering the processed parts ready for assembling or packaging. Available with either ribbon or silicon carbide resistors, the furnaces provide reliable, continuous operation with minimum maintenance. Heavy insulation keeps operating costs down and eases working conditions around the furnace. Since these furnaces can achieve substantial cost reductions and quality improvements, they are extremely popular; over 200 General Electric mesh-belt furnaces are now in operation.

Ask your General Electric sales engineer for complete data on G-E mesh-belt furnaces or write for bulletin GED-3881. General Electric Company, Schenectady 5, New York. 756-01

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 1336 on Page 48-A

New Model H-120 Hough "PAYLOADER" built to scoop 20% more load because of the great strength of USS MAN-TEN and "T-1" Steels.

USS "T-1" and MAN-TEN Steels cut 1 ton of dead weight from this bigger PAYLOADER®

Two thousand pounds of weight have been chopped from the front end of this new Hough H-120 "PAYLOADER" by designing with USS "T-1" and USS High-Strength Steels. Result: one ton more capacity . . . increased reach and dumping height . . . better balance . . . stronger construction . . . lower operating costs.

This is another case where the greater tensile properties of the high-strength steels and the *extra* high strength of USS "T-1" Steel (100,000 psi minimum yield strength) made possible a superior designed machine. About 4,000 pounds of USS "T-1" Constructional Alloy Steel in ½" and ¾" plate and ½" x 5" bars are used in the boom arms, rocker arms, and bucket attachment brackets. The bucket is 5/16" USS MAN-TEN Brand High-Strength Steel—a 50,000 psi minimum yield point grade.

The bucket lift assembly was designed to a working stress, which, multiplied by a reasonable safety factor, comes up to the full minimum yield strength of "T-1" Steel. The 2,000 pounds of weight saved went directly into increased payload capacity—20%. The new "PAYLOADER" can handle 12,000 pounds instead of the 10,000 pounds of the experimental design. This is just what the customers wanted. No other steel offered such a high ratio of strength to weight.

The first 150 of these Hough tractor shovels are already giving outstanding service. More are being built. The combination of USS "T-1" and MAN-TEN Steels in the new "PAYLOADER" provides high strength with low total cost, lighter weight and freedom from maintenance.

For more information on any of these USS special steels, write to United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

The Frank G. Hough Co. is a subsidiary of International Harvester Co.

USS, "T-1" and MAN-TEN are registered trademarks of United States Steel. "PAYLOADER" is a registered trademark of The Frank G. Hough Co.

United States Steel Corporation – Pittsburgh
Columbia-Geneva Steel – San Francisco
National Tube – Pittsburgh
Tennessee Coal & Iron – Fairfield, Alabama
United States Steel Supply – Steel Service Centers
United States Steel Export Company

United States Steel

This is a space ship floor maker

Sometime within the next several years, the first American will soar into orbit around the earth. He will be sealed in a small, cone-shaped space capsule mounted atop an Atlas missile. The missile will climb 100 miles in less than six minutes, where the capsule will disengage and go into orbit. The man will be alone in space.

The vehicle for this historic voyage is already in production, under the auspices of the National Aeronautics and Space Administration's "Project Mercury." One of the possible methods of heat protection is a beryllium heat sink, forged on two giant steel dies. Both dies are USS Quality Steel Forgings. The top die (shown being rough-machined on one of our vertical boring mills) will be convex, 20 inches thick and will weigh 26,520 pounds. The bottom die, concave and 18 inches thick, weighs 27,700 pounds. Both are 92 inches in diameter.

The heat sink of the space capsule will also be its leading face when re-entering the atmosphere. It will be traveling 18,000 miles per hour, subject to thousands of degrees of temperature and many times the force of gravity. Naturally, it has to have superb strength and heat-resistant characteristics. By the same token, the dies that shaped the capsule floor had to be perfect.

After forging, both dies were subjected to preliminary heat treating and preliminary machining. Then came quenching and tempering. A battery of tests followed: ultrasonic inspection, tangential tensile tests, Charpy V notch impact tests, grain size tests, bend tests and magnetic particle inspection. Only then were the dies ready to take the incredible forging pressure, exerted by the giant hydraulic closed-die forging press where the beryllium disc was formed.

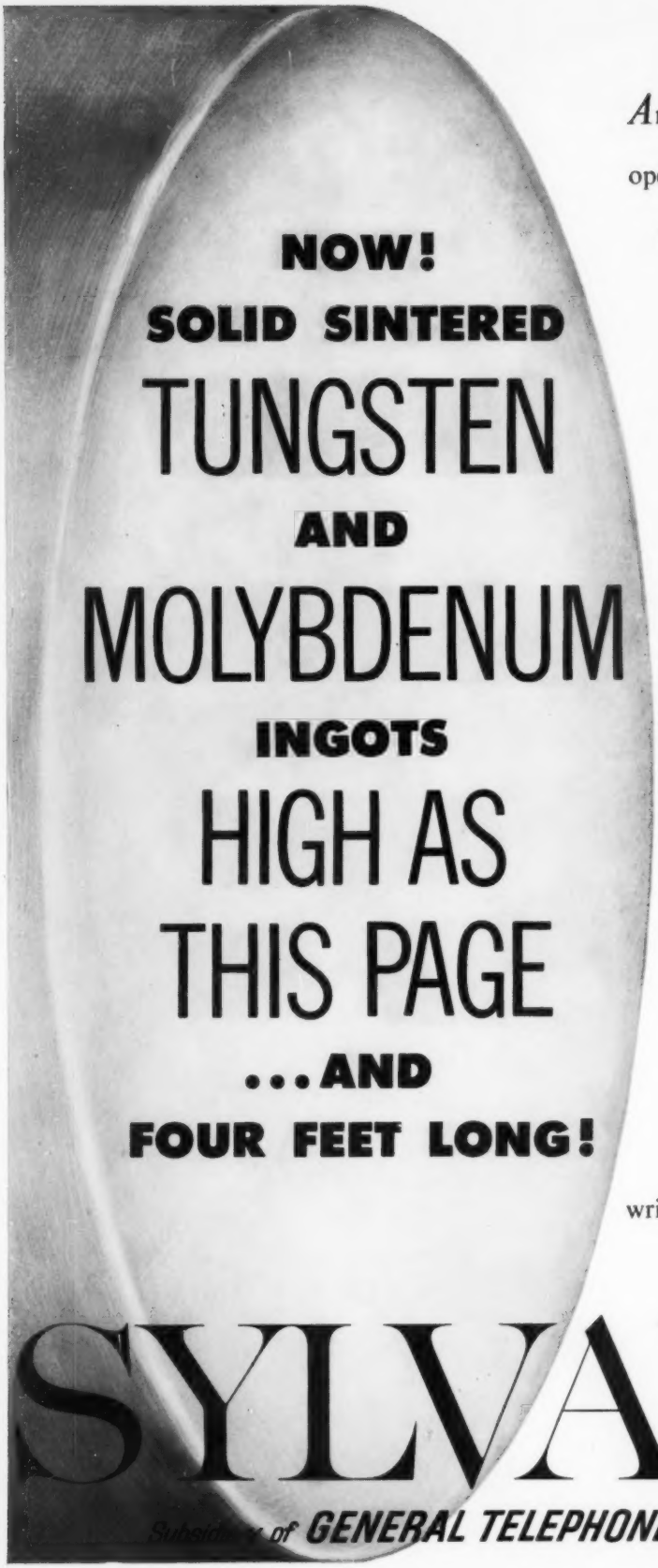
We invite your inquiries or requests for our free 32-page booklet on USS Quality Forgings. Just write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS is a registered trademark

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Export Company

United States Steel

USS



NOW!

SOLID SINTERED

TUNGSTEN

AND

MOLYBDENUM

INGOTS

HIGH AS THIS PAGE

...AND

FOUR FEET LONG!

Another first from Sylvania! A dramatic new isostatic pressing and sintering operation now makes it possible to supply missile and rocket makers with refractory metal ingots big enough for direct fabrication into their largest parts requirements.

By this process Sylvania can now produce 100% tungsten or molybdenum ingots up to 10″ in diameter, 4 feet long! Various combinations of these elements are possible, too.

You can order ingots in a variety of sizes and shapes: rectangular, cylindrical or hollow cylinders. Special sizes and shapes are handled, too, on a special inquiry basis.

The fine grain structure achieved by this Sylvania process allows direct physical working of the material by rolling, forging or extruding.

In many cases, the smooth, clean, carbide-free surface eliminates the need for costly surface machining.

The process is relatively inexpensive, which means lower prices per pound for you over competitive processes.

If you're working with high-temperature metals requiring prefabricated ingots or consumable electrodes, Sylvania can help you. Call your Sylvania representative, or write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pa.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

Circle 1350 on Page 48-A

Really Tough Where the Power Hits the Ground—thanks to TOCCO* Induction Heating

The Eimco Corporation of Salt Lake City manufactures heavy-duty earth moving and mining equipment of many kinds. All of their equipment must be engineered for tough work in the roughest kind of terrain, and all of it runs on tractor track that must stand up to the toughest abuse.

Superior Quality

Recently Eimco installed a 100 kw, 10,000 cycle TOCCO machine for heat treating track links. This equipment assures a completely uniform hardness pattern—the same every time for one link or one million. Furthermore, the parts are drawn as well as hardened by one TOCCO machine with one operator.

Increased Production

In addition to superior quality, TOCCO increased track link production over 400%. Formerly, one man could produce 35 links per hour; now, with TOCCO, he produces 150!

Whether you're looking for product improvement, increased production, or lower unit costs, it will pay you to investigate TOCCO Induction Heating.

THE OHIO CRANKSHAFT COMPANY

Mail Coupon Today—NEW FREE Bulletin

The Ohio Crankshaft Co. • Dept. R-4, Cleveland 5, Ohio

Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating."

Name_____

Position_____

Company_____

Address_____

City_____ Zone____ State_____

Circle 1337 on Page 48-A

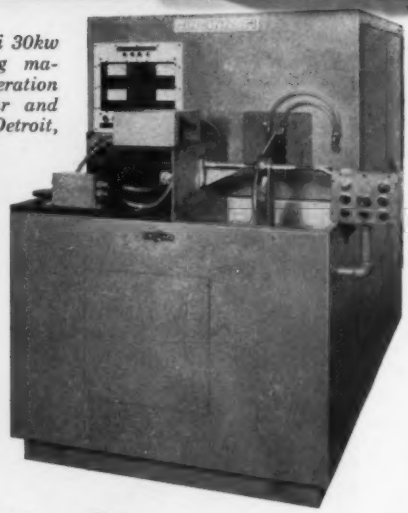


Fig. 1. Cincinnati 30kw Inductron heating machine now in operation at Dearborn Gear and Tool Company, Detroit, Michigan.

70 *more than specified!*

Required by Dearborn Gear & Tool Co., Detroit: a method for rapid hardening 3½″ of the bearing surface and spline of automobile starter armature shafts (part shown above). Minimum hardness, 40 Rc; .010″ - .030″ depth; 460 parts per hour, minimum rate.

The economical solution: A 30kw Cincinnati Inductron heating machine, plus ingenious tooling developed by Cincinnati's Heat Engineers. The photos below show the tooling that maintains a constantly uniform specified hardness pattern throughout a production rate of 530 parts per hour. And that is 70 more parts per hour than the minimum rate required.

530 ARMATURE SHAFTS PER HOUR HARDENED BY A CINCINNATI INDUCTRON AT DEARBORN GEAR & TOOL COMPANY

Cincinnati builds *both* Flamatic® flame heating, and Inductron® induction heating machines. For detailed information on how you can obtain top efficiency and economy for your heat processing work, call in a Meta-Dynamics Division field engineer. Backed by the resources of Cincinnati's completely equipped and staffed heat engineering laboratories, your needs will be thoroughly analyzed, your parts "test run," and specific, unbiased recommendations made.

Fig. 2. Shafts are received in hopper and positioned so that a horizontal, multiple-speed cam feeds the parts through the coil. Cam has OD contoured to provide the proper feed rate for the different diameters of the part. When the required 3½″ length is heated, limit switch cuts off current as the remainder of the shaft is rapidly passed through coil. Heat cycle is again energized as next shaft enters coil.

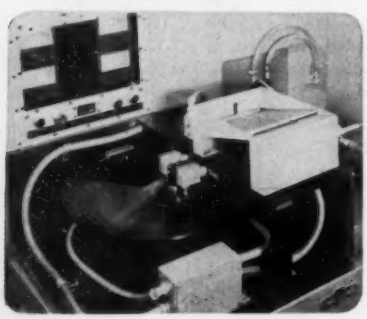


Fig. 3. Close-up view of heat-quench area showing one shaft entering discharge chute while another shaft is passing through coil. Quench head is positioned adjacent to the coil and applies spray quench to the areas of the part that have just been heated. Three shafts are always in line, and parts are continuously fed through the coil, one shaft pushing another.

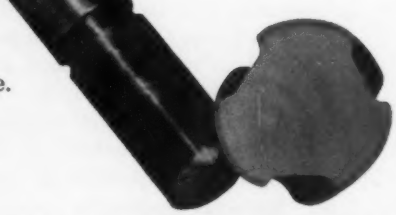


Fig. 4. Cross section of splined area of armature shaft, showing uniform pattern of .020″ minimum case depth. Minimum hardness achieved is 40 Rc.

inductron flamatic
hardening machines
META-DYNAMICS DIVISION
Machines for Metal Forming and Heat Treating
THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio, U.S.A.
CINCINNATI

Circle 1338 on Page 48-A

NEW LITERATURE

Ferrous Metals

1045. Strong Stainless

Technical booklet "AM 350 and AM 355" gives the properties and fabrication behavior of these two precipitation hardening stainless steels serviceable to 1000°F. and higher. *Allegheny Ludlum*

1046. High-Strength Steels

Data sheets on "Vac-Arc" (consumable vacuum melted) alloys of the toolsteel family heat treated to about 250,000 psi. yield and suitable for hot bearings, aircraft and missiles. *Latrobe Steel Co.*

1047. Specialty Steels

Physical property charts are available giving the tensile strength and forming properties of a wide variety of high-carbon or spring steels as cold rolled strip. *Wallace Barnes*

1048. Quality Steels

All operations from the melting of electric steel to heat treatment and cold working are described in 48-p. booklet "Aristoloy Products & Facilities" by *Copperweld Steel Co.*

1049. Stainless Steel

Republic Steel Corp. has brochures and data sheets on the wide variety of stainless and corrosion resistant steels made by them.

1050. Low-Alloy Steel

Helpful Data Bulletin No. 21 by *La Salle Steel Co.* tells how to use "stressproof" steel in maintenance and repair work. It is a copper bearing 1.5% Mn steel (0.45%C), heat treated, drawn and stress-relieved.

1051. Alloy Steels

Series of data sheets giving facts about analysis, heat treatment, fabrication and uses of A.I.S.I. standard steels and several special-analysis steels. *Bethlehem Steel Co.*

1052. Spring Steel

Brochure gives data on "2 R 25", a superior stainless spring steel, tough, resiliant, formable. It has fatigue life 10 fold that of carbon spring steel. *Sandvik Steel, Inc.*

1053. Rimming Steel

Information on "MCA" flux containing rare earths and its effect on producing uniformity in large ingots of rimming steel. *Molybdenum Corp. of America*

1054. Contour Rolled Stock

Contoured bars and strip, with tolerances to 0.001 in., fine finish and controlled temper presented in literature from *D. E. Makepeace Division of Engelhard Industries, Inc.*

Nonferrous Metals

1056. Aluminum Bronze

"Ampco Welding News" is a quarterly published by *Ampco Metal, Inc.* The current number includes an article on an aluminum bronze alloy that resists stress-corrosion cracking.

1057. Refractory Metals

Complete information on tungsten and molybdenum, available in various forms from powders to pellets to arc-casting electrode to 10-in. ingots, 4 ft. long. *Sylvania Electric Products Inc.*

1058. Rare Metals

Information on ultra-pure rare metals such as yttrium, gadolinium, and other rare earths. *Lunex Co.*

1059. Cb-Ta-Zr Alloy

Technical Bulletin on "Fansteel 82 Metal," more oxidation resistant than pure columbium. With 15,000-psi. yield and 14% elongation at 2400°F. it is easily workable and weldable. *Fansteel Metallurgical Corp.*

1055. Furnace Brazing

A series of 14 articles on brazing was written some years ago by H. M. Webber of G.E.'s Industrial Heating Section, and later assembled in a 50-p. bulletin. It has proved so popular and useful

that a re-reissue has been warranted. The document contains a wealth of down-to-earth information on how to do it, what to use, and what results can be expected from electric-furnace brazing. *General Electric Co.*

1060. Lithium

Folder gives brief case histories showing how Technical Service Division of *Lithium Corp.* has cooperated with eight leading metallurgical producers to degasify or deoxidize a molten alloy or to strengthen by alloying.

1061. Powder Metals

Nickel and cobalt metal powders can be more readily formed into compacts of controlled analysis by coating the original grains with the required amount of the second metal. Information about such "Sherritt" coatings from *Foote Mineral Co.*

1062. Molybdenum Alloys

Climax Molybdenum Co. has issued, in its series of "Technical Notes," a 12-p. document listing pertinent scientific literature on constitution diagrams of 60 binary systems and 86 more complicated ones.

1063. Tin

A monthly publication called "Tin News" presents information on world supply and prices of tin as well as properties, uses, and manufacturing processes of tin and it alloy. *The Malayan Tin Bureau*

1064. Aluminum Pig and Ingot

12-p. Form 28-114-10 lists standard forms and packaging methods and analyses and characteristics of various alloy ingots adaptable for sand, permanent mold or for die castings. *Aluminum Co. of America*

1065. Continuous-Cast Bronze

Complete data on "Asarcon" continuous cast bronze bars, tubes, shapes (gear toothed) and the economical production of parts therefrom. *American Smelting & Refining Co.*

Heat and Corrosion Resistant Materials

1066. Insulation

Blocks formulated from asbestos and diatomaceous silica (called "Superex") described in IN-190A by *Johns-Manville.* 12 pages of design and technical data.

1067. Alumina Castables

Norton Co. has issued a new catalog showing two types: "Alundum 33-I" (fused Al_2O_3 bubbles) and "Alundum 33-HD" (dense fused grains) and showing their utility.

1068. Super-Refractories

Technical Note TICSN-42 gives thermal and electrical characteristics, baking schedules and temperature limits of several "Durock" formula-

PUNCH IT... FORM IT... SHEAR IT... SOLDER IT!

New G-E CLAD-MOLY SHEET won't blister, flake or peel even if you heat it to 950°C

G-E Clad-Moly is molybdenum sheet clad in either nickel or copper, developed by General Electric. It meets the needs of the electronic industry for a molybdenum sheet with good soldering characteristics. What's more, this cladding really sticks! Won't delaminate! Bonds like a single piece of metal!

Base material is General Electric HD Moly Sheet, a new, high ductility sheet of pure molybdenum. The G-E Clad-Moly Sheet retains all the favorable properties of molybdenum—like its coefficient of thermal expansion that's similar to silicon, and its high electrical conductivity.

Order G-E Clad-Moly Sheet in thicknesses of from 0.010 to 0.080 inches—in widths up to 4 inches. Specify copper or nickel cladding on one or both sides. (Cladding will be between 0.0005 and 0.001 inches thick.) Or you can special order the *cladding thickness* up to 10% of *total sheet thickness.*

WIDEST USE AT PRESENT— G-E Clad-Moly is ideal for disks in silicon power rectifiers (see disks in photo above). It gives them excellent soldering properties. But there's no limit to the possible uses of this new material. We'd like to work with you in tailoring just the right G-E Clad-Moly to your specific needs. General Electric Co., Lamp Metals and Components Dept. MP-40, 21800 Tungsten Road, Cleveland 17, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 1339 on Page 48-A

tions for missile nose cones and exhaust liners. *Physical Sciences Corp.* (formerly *Technical Industries Corp.*)

1069. Superalloys

36-p. brochure is a complete presentation of all details concerning the manufacture of vacuum melted alloys, and compares their properties with those of others of the same analysis melted in conventional ways. *Metals Division of Kelsey-Hayes Co.*

1070. High-Temperature Alloy

Booklet "Hastelloy Alloy X" presents its outstanding corrosion-resistant properties to 2000°F. *Haynes Stellite Co.*

1071. Metallized Components

Technical Bulletin M-100 gives data on metallized ceramic alumina, glass or mica components which can be brazed to metallic conductors. *Metalizing Industries, Inc.*

1072. High-Purity Alumina

New catalog on refractories includes data on 99.7% Al_2O_3 for tubes and crucibles for high-temperature (up to 3550°F.) operation. *Morganite, Inc.*

1073. Substances for Severe Service

Carborundum Co.'s pamphlet "Materials for Advanced Technology" gives the properties of some 26 new products, mostly oxides, carbides, nitrides and borides.

1074. Magnetic Alloys

Technical Data Sheets 501, 503 and 505 describe physical properties of vacuum melted nickel-iron alloys, permalloys, and aluminum-iron soft magnetic alloy "Alfenol." *Precision Metals Div. of Hamilton Watch Co.*

1075. Fused Quartz

Literature has been issued by *Engelhard Industries, Inc.*, concerning "Amersil" high-purity fused quartz tubing, crucibles, trays and boxes.

Nuclear Materials

1076. Mechanical Arms

Flyer describes Model 550 with arm stretch of 18 ft., eight motions and 100 lb. capacity, and a small Model 150, a remote-controlled motor-driven device with six motions and a 360° shoulder swing. *General Mills*

1077. Nuclear Graphite

8-p. brochure entitled "'National' Nuclear Graphite" describes many unique properties of the material for high-temperature fuel elements in various shapes. *National Carbon Co.*

1078. Circulating Systems

"Conoseal" catalog shows how "Marman" Joints make dependable leak-proof joints and seals in tubing carrying gas, liquid, vacuum or liquid metal. *Aeroquip; Marman Division*

1079. Safety Enclosures

Illustrated folder describing 22 kinds of "off-the-shelf" enclosures, fume hoods, vacuum dry boxes and safety cabinets available from *S. Blickman, Inc.*

1080. Safety Badges

Information available from *Picker X-Ray Corp.* on "Guardray," a film badge which reports X- and beta-radiations separately.

1081. "Boral" Sandwich

Effective shield against thermal neutrons is a sandwich of boron carbide dispersed in aluminum, clad on both sides. Information from *Brooks & Perkins, Inc.*

Tool Materials

1082. Hack Saw Blades

Armstrong-Blum Mfg. Co. offers bulletin on "Marvel" hack saw blades —a bi-metal with high speed edge and carbon steel band.

1083. Toolsteel

Information available about "Molite" (M2 high speed steel) having a good balance of toughness, red hardness and resistance to wear from *Columbia Tool Steel Co.*

1084. Hand Torches

Air Reduction Sales Co. has revised its 36-p. Catalog 818 setting forth in detail their complete equipment for cutting, welding, brazing, heating, descaling and flame hardening.

1085. Wire Straightening

Bulletin 751 on machinery for straightening and cutting wire. *Vaughn Machinery Co.*

1086. Knurling Machine

Descriptive material on an adaptation of a hand-operated marking machine which enables it to knurl the ends of shafts (steel, brass or aluminum) prior to fitting into gears or wheels. *M. E. Cunningham Co.*

1088. Slitters

Full line of gang slitters and accessories detailed in Bulletin 569, ranging from light duty to heavy duty pull-through designs. *Stanat Mfg. Co.*

1089. Colloidal Graphite

Booklet "The Biggest Ounce of Protection" describes advantages of colloidal graphite as a lubricant for aluminum extruding. *Grafo Colloids Corp.*

1090. Brazing Carbide Tips

Step-by-step instructions for attaching carbide cutters to toolsteel shanks are given in Bulletin 11-B, recounting the various advantages of brazing with silver alloys. *Handy & Harman*

1091. Die Steel

Performance Report No. 20 gives a case history of how grinding and machining time on a typical progressive die was cut more than 25% by use of "Lo-Air" toolsteel. *Universal Cyclops Steel Corp.*

1092. Strip Shears

Hydraulically operated, mill mounted shears for cutting fishtails from leading and trailing ends of strip and sheet up to 84 in. wide are remote operated from roller's control panel. Details available from *Curry Air Shear Corp.*

1093. Rubberized Abrasives

Case histories of typical applications of rubber - bonded abrasive wheels, their mounting and dressing and recommended speeds, are given in 8-p. manual by *Cratex Mfg. Co.*

1094. Cutting Processes

Brochure describes in-plant courses to suit needs of your company. *Metals Engineering Institute*

1095. 50-Ton Shear

Flyer describes advantages of self-contained, motor-driven unit for shearing bars up to 1 in. square and angles up to 4-in. leg. *Shearease Co.*

1096. Graphite Dispersions

Acheson Colloids Co. has issued Bulletin 426 explaining the various uses in the metal working field—especially "Prodag" for spray lubricating dies for forging brass and bronze.

1097. Safety Tools

24-p. catalog lists a large variety of safety (non-sparking) hand tools of forged beryllium copper. *Ampco Metal.*

1098. Carbides for Machine Parts

Uses of hard carbide formulation "Kennametal" (W, Ti and Ta carbides) for other uses than the usual cutting tools are listed in Booklet B 111A, *Kennametal, Inc.*

1101. Carbide Drill Blanks

Information available from *Atrax Co.* on a series of wire-size drill blanks, 1 to 80 gage (0.0135 to 0.2280 in. diameter) precision ground of C-2 grade carbide.

1102. Drop Forging Hammer

28-p. bulletin on "Ceco-Drop" explains the place this improved hammer has in modernized forge shops. *Chambersburg Engineering Co.*

1103. Diamond Pins

Data on toolsteel pins covered with diamond particles uniformly distributed and tightly attached by "Chrome-Lok" process. *Titan Tool Supply Co.*

Industrial Heating

1104. High-Temperature Furnace

"Hotpot" is a laboratory furnace large enough for a 6-in. crucible. Fired with oxy-acetylene or oxy-propane mixtures and capable of reaching 4600°F. Information available from *Zirconium Corp. of America*

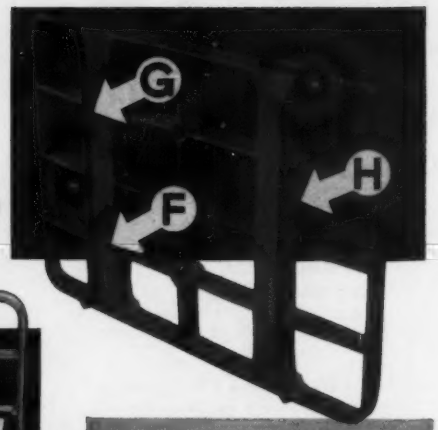
1105. Plate and Bar Heater

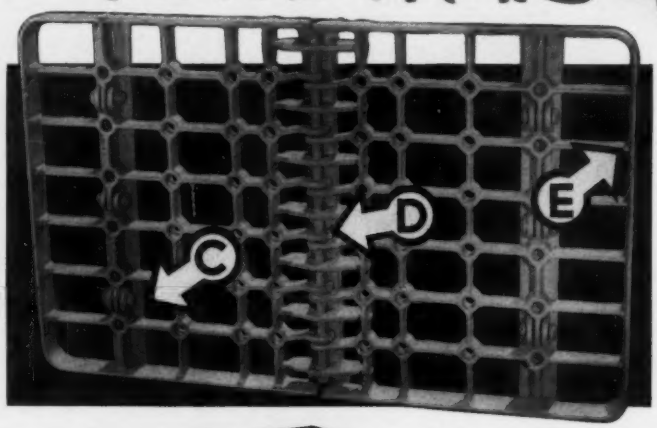
16-p. booklet illustrates very large furnaces for continuous heat treating of heavy plate (up to 3 in. thick and 14 ft. wide) of carbon and alloy steel. Bulletin B-91. *Drever Co.*

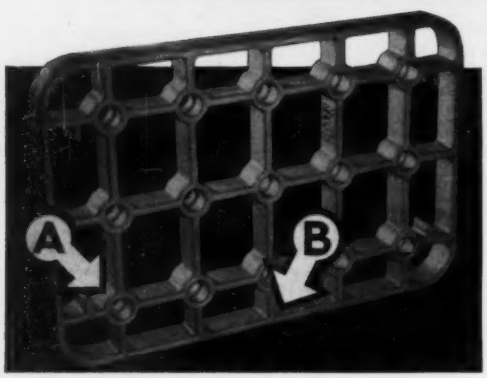
1106. 2000°F. Oven

The largest "Buzzer" furnace now measures 36 in. wide, 72 in. long and 36 in. high. It has a silicon carbide hearth and six atmospheric venturi burners with external pilots. Descriptive literature available from *Charles A. Hones, Inc.*

ENGINEERING GIVES Better Service ON FURNACE TRAYS







Why DO AECCo. TRAYS CONSISTENTLY GIVE BETTER SERVICE?

A UNIFORM SECTIONS AND BARREL CORES AT INTERNAL INTERSECTIONS — BETTER CASTINGS AND LESS THERMAL STRESS IN USE.

B CONTROLLED FINE GRAIN STRUCTURE AT EXTERNAL INTERSECTIONS—BETTER FATIGUE LIFE ASSURED.

C SHOES PROVIDED FOR RAIL SUPPORTS AS REQUIRED.

D AECCo. PROPRIETARY HINGE DESIGN FOR EQUAL LOADING ON THREE RAIL FURNACE APPLICATIONS.

E FULL RADII EVERYWHERE—NO SHARP CORNERS TO ACT AS NOTCHES FOR FATIGUE FAILURES.

F TUBULAR COMPRESSION MEMBERS AND RAIL SUPPORTS—FOR INCREASED STIFFNESS, AND STRENGTH WHERE STRENGTH IS NEEDED.

G INTEGRAL FLANGE ON TUBE SERVES AS RAIL GUIDE.

H GENEROUS OPENINGS FOR ATMOSPHERE AND QUENCH CIRCULATION CONTRIBUTE TO LONGER LIFE.

Because OF BALANCED DESIGN—ATTENTION TO DETAIL — PROPRIETARY PROCESSES and PRODUCTION KNOW-HOW

FURNACE TRAYS—of all types, sizes, and configurations—are an AECCo. specialty. We treat each tray design and order as an opportunity to apply our experience and knowledge in heat resistant alloys, and to create better HIGH TEMPERATURE TOOLING for the user.

SERVICE RECORDS—in the plants of many customers—confirm that AECCo. furnace trays do a better job and last longer. Note Accoloy Pointers for a few of the details which contribute to these results.

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ALLOY ENGINEERING & CASTING CO.

1700 W. Washington St., Champaign, Ill. Tel: Fleetwood 6-2568

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

1109. Special Furnaces

Pacific Scientific Co. has literature about custom designed furnaces, such as one with car bottom which can braze honeycomb panels 6 by 12 ft. in dimension.

1110. Quenching Oils

Rodman Chemical Co. has a new 28-p. booklet giving data on surface quenching speeds, at various temperatures and their relation to hardness depth and distortion.

1111. Long-Lived Trays

Reprint of technical report "The Mechanism of Thermal Fatigue" and its relation to the life of heat treating grids, trays and fixtures is available from *Electro-Alloys.*

1112. Deep Freeze

Chamber, 6x3x3 ft., can chill 300 lb. of metal to −250°F. in 1 hr. Suitable for stabilization of stainless and alloys based on Mo, Ti or Ta. Needs only electrical and water connections. *Webber Mfg. Co.*

1113. Vacuum Furnace

Operating to 4200°F., equipped with "Radiation Shield," complete accessories within one mounting, for wide range of heat treating operations on shapes up to 10 in. major dimension. Bulletin GED-3793. *General Electric Co.*

1114. Radiation "Pyrometer"

Range from zero to 200°F. achieved by "Velotron" pyrometer systems. Data sheets describe automatic compensation for ambient temperature. Measures temperatures of stationary or moving objects. *The Bristol Co.*

1115. Oxidation Resist

Navan Products Division of North American Aviation has issued folders describing three "Skalix" chemicals sprayed or dipped on stainless steels and nickel or cobalt-base alloys to protect them from oxidation during long heating at 2000 to 2500°F.

1116. Blowers

Catalog 126C from *The Spencer Turbine Co.* describes a line of simple, rugged and compact blowers with bearings outside the casing.

1117. Accurate Heating Furnaces

Bulletin SC-182 describes how "Surface Power Convection" gives exceptional uniformity and speed of heat treating and carburizing. *Surface Combustion*

1118. Thermocouple Glands

Tiny devices to be screwed into a container wall so a small bare junction is exposed within yet the joint is pressure tight from 0.005 microns to 5000 psi. pressure are described in flyer by *Conax Corp.*

1119. Conveyor Belts

Brochure on above title discusses metal-mesh belts for continuous movement of parts through all heat treating operations. *The Cambridge Wire Cloth Co.*

1134. Brass Annealing

A furnace for annealing continuously brass strip at speeds up to 200 ft. per min., uniformly edge to center, by virtue of unprecedented velocity of convection currents in the furnace atmosphere. Bulletin SC-182, *Surface Combustion*

1135. Vacuum Furnaces

Consolidated Electrodynamics' Bulletins P4-30 and 32 explain how a basic furnace and pumping system of 50-lb. melting capacity can be expanded as desired to 200 lb.

1136. Practical Heat Treatment

32-p. booklet describes lesson courses in fundamentals, suitable for home study or in-plant training programs. *Metals Engineering Institute*

1137. Ovens

Bulletin 157 presents full line of batch and conveyor types of ovens operating up to 1000°F. *Young Brothers Co.*

1138. Vacuum Equipment

A wide variety of heating equipment for melting, metallizing and sintering in production or research is shown in literature available from *F. J. Stokes Corp.*

1139. Quenching Salt

The advantages of a salt with working range between 325 and 1100°F. called "Thermo-Quench" are given in Technical Bulletin H-19 by *Park Chemical Co.*, especially for interrupted quenching processes and tempering.

1140. Salt Baths

American Cyanamid Co. have available for distribution technical data sheets about salt baths for heat treating without changing the surfaces of the metal parts.

1141. Induction Heating

56-p. catalog describes complete line of induction heating equipment for hardening, brazing, billet heating, sintering and shrink fitting. *Induction Heating Corp.*

1142. Castable Refractories

Bulletin R-35A contains information on refractory castable linings for heating and heat treating furnaces large and small. *Babcock & Wilcox.*

1143. Carburising Box

Data on boxes pressed from ⅛-in. sheets of Type 330 stainless, unusually resistant to carburizing and nitriding and oxidation resistant to 1950°F., available from *Wiretex Mfg. Co., Inc.*

1144. Gas Analyzer

Methane, moisture, and carbon oxides in furnace atmospheres analyzed by "LIRA Infrared Model 300." Complete information in bulletin from *Mine Safety Appliances Co.*

1145. Carburizing

Reprint of article on "High Temperature Carburizing" (up to 2000°F.) available from *Ipsen Industries, Inc.*

Cleaning and Flushing

1155. Chromate Conversion Coatings

Booklet "Process Chemicals" describes the "Iridite" specialized line of chromate conversion coatings for nonferrous metals—dip, brush or spray—manual or automatic. *Allied Research Products, Inc.*

1156. Solvent Degreasing

Reprint of article "Solvent Degreasing—What Every User Should Know" available from *Detrex Chemical Industries, Inc.*

1157. Cleaning Equipment Modules

Adaptability of standardized modules in assembling new lines (or adapting old lines) of production equipment for power spray washing and phosphatizing is shown in Bulletin 659-1 of *Ramco Equipment Corp.*

1158. Aluminum Stripper

Bulletin F-7893 tells how "Oakite Stripper S-A" cleans aluminum parts of defective paint, lacquer and plastic finishes. *Oakite Products, Inc.*

1159. Drying Assist

Case history of trouble encountered in bicycle plant. Frames rusted along brazed joints. "Kenvert Aquanol" added to rinsing solutions stopped the staining and did not interfere with subsequent phosphating and painting. *Conversion Chemical Corp.*

1160. Selective Plating

Brochure describes power pack, plating tools and solutions for building up worn areas, stopping-off prior to carburizing, or fitting bearings by the "Dalic" process. *Sifco Metachemical, Inc.*

1161. Polishing Dip

Stainless steels of the 300 series can be polished (slight scratches and mars levelled off) by simple dip in "Ox-Off Lustre Dip." Data from *Chemclean Products Corp.*

1162. "Plasmatron" Spray Gun

Illustrated brochure on gun producing an ionized jet of gas at temperatures about 30,000°F., capable of spraying dense coatings of borides, carbides and refractory oxides. *Plasmadyne*

1163. Gold Plating

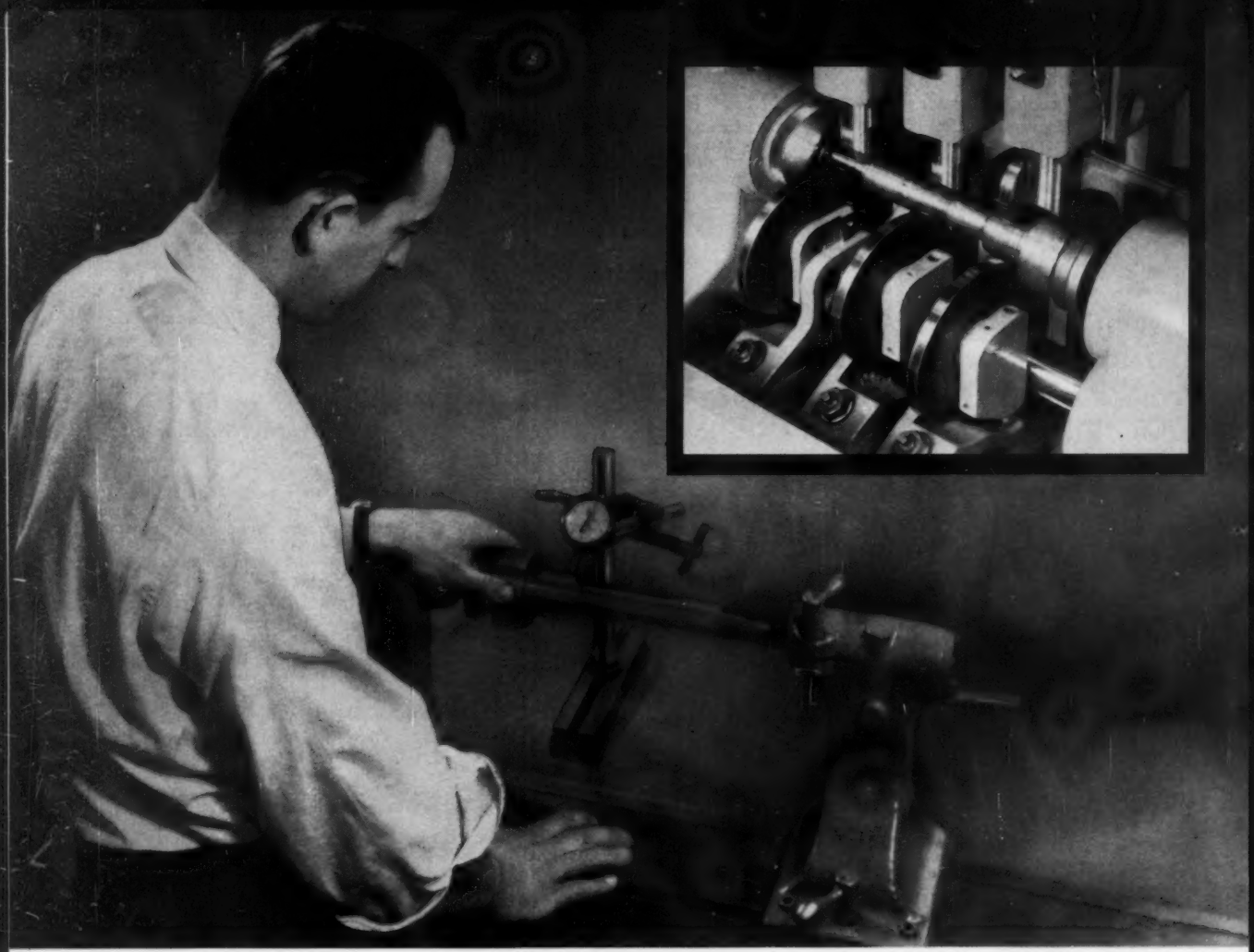
Technical Paper 150 B-2 includes operational data for gold electroplating solution called "Autronex," a low pH formulation for industrial applications. *Sel-Rex Corp.*

1164. Silver Brazing

Handy & Harman's Bulletin 20, "Easy-Flo and Sil-Fos" gives details on silver brazing alloys, heating methods, joint design and production techniques.

1165. Cleaner for Steel

Bulletin 2A describes "Clarco Elec-



How this shaft was quenched and straightened *at the same time*

This shaft reads true because it was not allowed to distort during hardening.

The manufacturer used a Gleason No. 140 Rolling Quench Machine to straighten the shaft *while it was being quenched.*

Since cold straightening was completely eliminated, he saved valuable production time and expense.

The quenched shaft also has less residual stress.

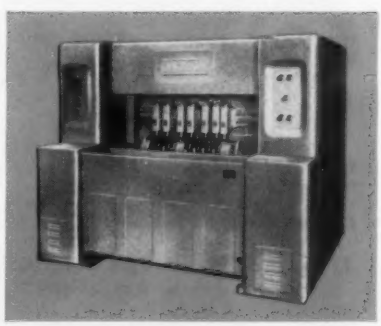
With this machine you roll parts under pressure continuously as you quench them. The operator puts the hot part on the lower rollers and starts the machine.

From there on the operation is automatic. Rolling speed, pressure and oil flow have been pre-set to meet specifications.

The Gleason No. 140 Rolling Quench Machine is suited equally well to both small and large quantity work. It accommodates shafts $\frac{3}{16}$″ to 4″ in diameter, 6″ to 40″ in length, with integral cams or shoulders up to 8″ diameter.

Tooling can be arranged to hold parts on diameters or centers. Unusual shapes can be handled with additional tooling.

Write for further information.



The Gleason No. 140 Rolling Quench Machine also handles multiple quenching of short shafts.

GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

Circle 1341 on Page 48-A

trocleaner 751," a heavy duty cleaner for steel, usable in both soaking and cleaning tanks. *Clarkson Laboratories.*

1166. Chromic Acid

Information available from *Solvay Process Division of Allied Chemical Corp.* on "Mutual" chromic acid used for anodyzing aluminum, pickling and bright dipping of many nonferrous alloys and as an active ingredient in chromate conversion coatings.

1167. Finishing Machine

Pangborn Corp. has data sheets on air-cushioned vibration machine for descaling and deburring, quiet and a fast worker.

1168. Plating Calculator

A slide rule which reads time required for any desired thickness of plate at any current density for eight different varieties of plate in common use is available from *Enthone, Inc.*

1169. Nickel Brightener

10-p. "Technical Brochure on 'NR' Nickel Barrel Brightener" describes this product and also gives tips on trouble shooting to correct operations on small parts. *The Seymour Mfg. Co.*

Welding and Joining

1175. Silver Brazing

Two complete reference manuals about low-temperature fluxing and silver "brazing" available from *Englehard Industries, Inc.*

1176. Furnace Brazing Techniques

16-p. Bulletin No. 592 of the above title by *The Electric Furnace Co.* discusses many practical aspects of the process and the specialized equipment available.

1177. Brazing Furnaces

Information on a wide variety of custom designed furnaces—box type, double elevator, through retorts, in-and-out muffle, and conveyorized. *Pacific Scientific Co.*

1178. AC–DC Welder

Information available about welding set capable of producing either 30-volt a.c. current (30 to 325 amperes) or 30-volt d.c. current (30 to 275 amperes) from *Hobart Brothers Co.*

1179. Flux Remover

Flyer describes "Ferro-Glo Flux Remover," a liquid metal cleaner, noncombustible, which rapidly removes all brazing flux from brass, copper or aluminum assemblies. *Gipson Co.*

1180. Brazing Salts

Park Chemical Co. has issued a technical bulletin about its "Aluminum Brazing Salt D," a stable salt bath for dip brazing.

1181. Capacitors

Federal Pacific Electric Co. has information on "Cornell-Dubilier" power capacitors which can be connected in banks and correct the power factor of a plant which absorbs peak electric loads as in heavy welding.

1182. Low-H Electrodes

Bulletin R-29 sets forth the advantages of *Harnischfeger Co.'s* "P & H Smootharc Welding Electrodes," low in hydrogen and proof against underbead cracking.

1183. CO_2 Process

Operating data for "Dual Shield" CO_2 welding process are contained in Brochure NH-636 from *National Cylinder Gas.* Butt welding, fillet welding, V-groove flat joints and spot welding are discussed.

1184. Spraywelder

Wall Colmonoy Corp.'s "Spraywelder" Catalog describes equipment for accurately hard surfacing parts to resist wear, such as aircraft engine valve stems.

1185. Spot and Projection Welder

A combination spot and projection welder, Model ARKN, takes 200KVA current and can weld 16-gage aluminum or 7-gage steel sheet. Operates under foot control or automatically at high speed. Information from *Alphil Spot Welder Mfg. Corp.*

1186. Metalworking Bulletin

This is the title of 24-p. bi-monthly publication by *Linde Co.* devoted to modern welding methods.

1187. Welding Mn Steel

Bulletin HS 203 gives details of operations and uses of "Wear-O-Matic WH", an open-arc electrode for making high-strength welds on Hadfield's manganese steel. *Alloy Rods Co.*

1188. Welding Outfit

"Five Star Pak," an all-purpose combination of torches, tips and gas regulators presented in Folder No. 17. *National Welding Equipment Co.*

1189. Hard Facing Electrode

Information is available from *Air Reduction Sales Co.* on an Electrode, "Nickel Manganese C", which work hardens to 550 Brinell. It contains 14% Mn and is suitable for surfaces which must resist battering wear.

Inspection and Control

1190. Gas Analyzer

8-p. brochure descriptive of "Model 213 Detector," a portable instrument for analyzing for traces of hydrocarbons in atmospheres or flues. *Perkin-Elmer Corp.*

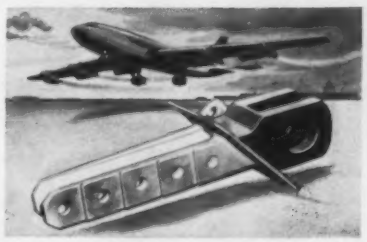
1191. Hot Plates

Plates up to 12 by 24 in. area, for either 115 or 230-volt current, with thermostat to hold any set temperature up to 700°F. within 5° tolerance, are illustrated in Bulletin HP-221. *Thermo Electric Mfg. Co.*

1192. Metallographical Equipment

Data and specifications covering complete line of metallographs, spectrographs, microscopes, and high and low-power cameras. *Bausch & Lomb Optical Co.*

NEWS from the NRC Vacuum MICRONICLE*

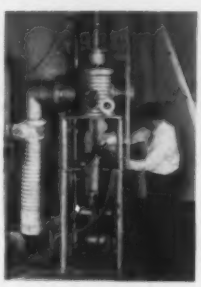


SAFER AIRCRAFT

Failure of high tensile steel aircraft parts such as landing gear structures have been traced to embrittlement from hydrogen picked up during electroplating. Such parts are now finished with a new vacuum cadmium coating process which provides protection against corrosion without causing embrittlement.

Thinner films of other metals are being vacuum deposited to develop improved semi-conductor and micro-molecular circuits and to produce low cost decorative finishes on metals and plastics.

PURER METALS WITH ELECTRON BEAM



Hard to melt materials such as tungsten, tantalum, zirconium, molybdenum, columbium and other high performance metals can now be melted without contamination. Electron beam can be used for either melting or contamination-free welding.

These furnaces can operate at highest vacuums attainable in a furnace and melt stock in any form. Melting temperature is almost unlimited. Heating can be concentrated or spread out as desired.

***FREE NRC Vacuum Micronicle**
a periodical containing details of above and other news about the field of high vacuum. Write on your company letterhead.

NRC EQUIPMENT CORPORATION

A Subsidiary of National Research Corporation
DEPT. M-1, 160 Charlemont St., Newton 61, Mass.
Circle 1342 on Page 48-A

CORROSION

How Lukens *Application Research* can help you find the right steel plate for the job

Migrating ions—superimposed on a photomicrograph of corroded steel plate—symbolize one of metallurgy's oldest assignments: the battle against corrosion. Developing new tactics in this constant campaign is the job of our Application Engineering staff.

For example, called on early in the planning stages, Lukens engineers recently attacked almost identical problems for two large processing companies—and came up with two completely different solutions.

The first involved a sugar refiner's vacuum pans. Frequent and costly cleaning was required to head off corrosion and product contamination. Our staff's prior research and experience in the food equipment field led it to suggest *nickel*-clad steel for the pans. (13% and 8% nickel-clad on A-285 backing steel.)

Cleaning and maintenance were equally costly to a leading chemical and dye company—in the protection of its nitrogen solution barge tanks. Here, our engineers found *stainless*-clad steel the most desirable answer. (12% 304L on A-212 backing steel.)

Armed with practical as well as technical knowledge of Lukens' wide range of special-duty steels, our Application Engineers have helped conquer corrosion on many fronts. That's why we say . . . *if your assignment is corrosion, let it be our assignment, too.* Contact Manager, Application Engineering, F-40 Services Building, Lukens Steel Company, Coatesville, Pa.

Helping Industry Choose Steels That Fit The Job

LUKENS

ASK FOR THE BULLETIN ON LUKENS CLAD STEELS

Circle 1343 on Page 48-A

1193. Hot Hardness Tester

Information available from *Marshall Products Co.* on vacuum furnace, Model 58-HD, wherein materials can be tested for hardness at temperatures up to 3000°F. Loading mechanism and sapphire indenter included.

1194. Spectrometry

Publication AS-14 describes many uses by leading automotive concern for X-ray emission spectrometry such as evaluating heat-treating processes, study of wear, analysis of metals and lubricants. *General Electric*

1195. Gamma Radiography

Bulletin presents "Iriditron" and "Multitron" units for gamma radiography whereby an entire circumferential weld can be inspected in a single exposure. *The Budd Co.*

1196. Portable Hot Plate

Lindberg Engineering Co. has published a pamphlet on its 1960 model "Pyrodisc" portable hot plate. Nichrome heating element keeps entire plate uniformly at any set temperature up to 750°F.

1197. Ultrasonic Inspector

Branson Instruments, Inc. have published Bulletin T-200 about the "Pulse-Echo Sonoray Model 5" flaw detector for contact or immersed use. It has an infinite choice of frequencies between 0.4 to 10.0 mc. per sec.

1206. Flaw Alarm

Bulletin T-205 describes accessory to ultrasonic flaw detector whereby alarms light up if instrument is out of order, or if the indication is beyond the "go-no-go" limits, or sound at some distant point. *Branson Instruments, Inc.*

1207. Automatic Control

Detailed description of "ASEA Pressductors" (pressure-sensitive plates) and their advantages for such things as measuring roll pressures in cold strip mills. *ASEA Electric, Inc.*

1208. Spring Tester

Bulletin available from *The Carlson Co.* on a rapid acting, motor driven spring tester, capacity 550 lb., taking springs up to 5 in. diameter and 20 in. long.

1209. Proving Rings

4-p. booklet P-260 from *Steel City Testing Machines, Inc.*, illustrates proving rings with dial indicators or optical devices and lists their uses and general characteristics.

1210. Gages

All sorts of gages are illustrated in 24-p. catalog and manual of *Regal Division, Beloit Tool Corp.*, including plug and ring gages, thread gages and plain gages.

1211. Small Vacuum Furnace

A laboratory furnace for arc welding is described in Bulletin 808. Power is derived from an ordinary d.c. welding generator. Vacuum to 10 microns is by mechanical pump. One electrical and one water connection are necessary. *New York Air Brake Co.*

1212. Smoothness Gage

Micrometrical Mfg. Co. has issued an 8-p. Bulletin LT14 showing construction and operation of "Profilometer", a portable instrument for indicating average roughness of a surface over which a probe is moved, either mechanically or manually.

1213. Corrosion Cabinet

Bulletin 401 gives specifications, sizes, and performance data on self-contained cabinets for accelerated corrosion testing in salty fog or humid atmospheres. *Industrial Filter & Pump Mfg. Co.*

1214. Sulphur Determinator

16-p. catalog contains photographs and information about "Dietert-Detroit" equipment for sulphur and carbon analysis, with necessary accessories. *Harry W. Dietert Co.*

1215. Multi-Point Recorder

Model 6702 can record up to 24 and has many simplified features. A solid-state constant current source eliminates standard cells and standardizing mechanisms. *Daystrom-Weston*

1216. Spectrograph

"Electrospec 200", a device measuring electron spin resonance, is said to offer great advantages in detecting defects in solids, measuring magnetic susceptibility, and study of oxide complexes in corrosion products. Folder from *Elion Instruments, Inc.*

1217. Temperature Indicator

"Thermomelt" pencils, liquids and pellets (visual temperature indicators) are described by *Markall Co.*

1218. Indentation Testers

Full line of equipment and accessories for hardness testing, manual, power and automatic, set forth in Catalog RT-58 by *Wilson Mechanical Instrument Division*

1219. Hardness Tester

Bulletin CRS60 gives data on motorized indentation hardness tester, capable of regular and superficial Rockwell tests in a single machine. *Torsion Balance Co.*

1220. Hardness Testers

Units for making all types of Rockwell hardness tests described in reference book by *Clark Instrument, Inc.*

1221. Hardness Inspection

Literature available on "Color-Glance" Brinell testers for 100% inspection of parts. Soft, correct, and too-hard items flash an appropriate light. *Steel City Testing Machines.*

1222. Portable Hardness Tester

"Impressor" (held down by hand) for measuring hardness of nonferrous metals. Read by dial indicator. *Barber-Colman Co.*

1223. pH Meters

Harshaw Scientific Division will send information on a line of Beckman pH meters ranging from pocket

Now available for prompt shipments in experimental quantities

RARE EARTH AND YTTRIUM METALS

In your unceasing search for promising new materials for metallurgical applications, you are sure to find it interesting and provocative . . . and quite likely rewarding . . . to investigate the rare earths.

Rare earth and yttrium metals are readily available from our inventory in a wide range of purities in experimental quantities. Primary forms are ingots, lumps and turnings. Costs are reasonable and advantageous for your research or product development operations.

Lindsay rare earths cover the whole gamut of rare earth technology, from crudes to highly refined materials. One of the significant properties of the rare earth metals is their scavenging ability for oxygen, sulfur, and some other non-metallics.

LOOK AT YTTRIUM, TOO

Yttrium shouldn't be overlooked either. It is available in grades ranging from high purity to crude alloys with magnesium.

Lindsay has been working with the rare earths for nearly 60 years, and is the world's largest producer of rare earth, yttrium, and thorium materials. We can furnish you with a considerable amount of interesting and revealing technical data on rare earth and yttrium metals, including a detailed tabulation of properties, purities, and costs.

Please ask for our bulletin "Rare Earth and Yttrium Metals." It will be sent to you promptly.

TRONA™

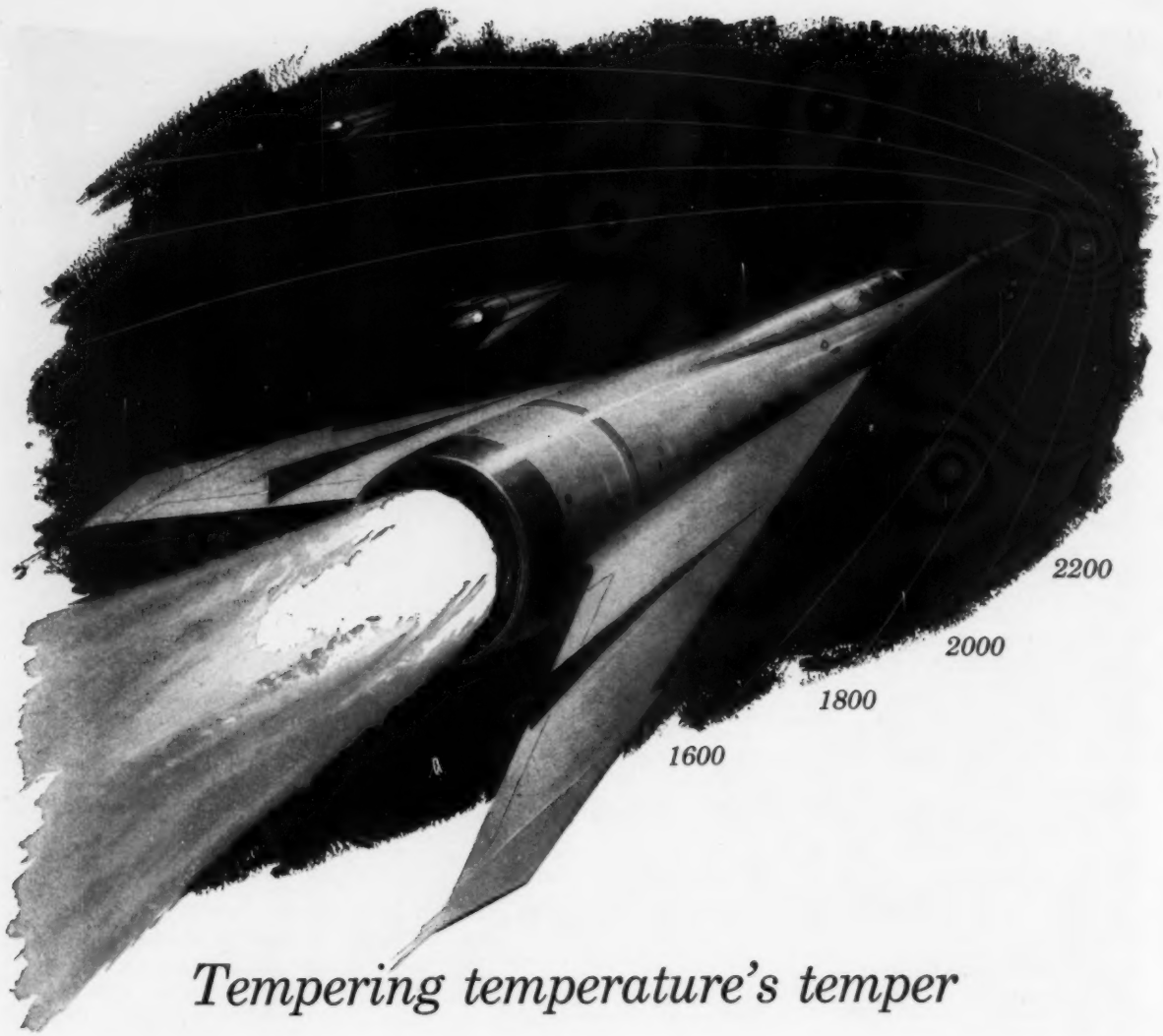
LINDSAY CHEMICAL DIVISION

American Potash & Chemical Corporation

99 Park Avenue, New York 16, N.Y.

3000 West Sixth St., Los Angeles 54, Calif.

Circle 1344 on Page 48-A



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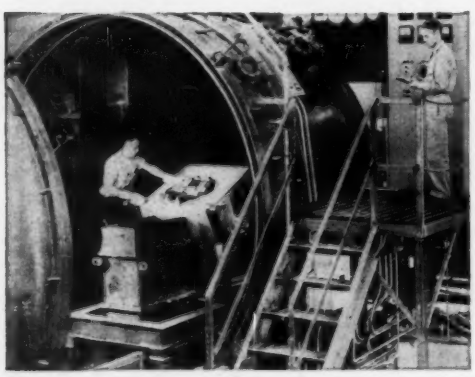

Complete vacuum melting equipment is part of HAYNES STELLITE's modern plant facilities. For full details, write for 48-page descriptive booklet.

Heat of 2000+ deg. F. is generated in a supersonic jet's tailpipe. So is extreme vibration.

By far the best alloy tested for this critical component is MULTIMET alloy—one of 12 HAYNES alloys helping combat heat, stress, and erosion in the jet engine, missile, and rocket field.

HAYNES alloys are relied on for use in afterburners, turbine blades, nozzle vanes, and many other high-temperature parts. All 12 HAYNES high-temperature alloys are *production* alloys and are readily available. Some are vacuum melted. Some air melted. Some are cast, some wrought, some are produced in both forms.

HAYNES
ALLOYS

HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 420 Lexington Avenue, New York 17, N. Y.

"Haynes," "Multimet," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

Circle 1345 on Page 48-A

size to self-contained but portable units of high accuracy.

1224. Temperature Crayons

Information on "Tempilstiks" (temperature indicating crayons). Eighty different ratings from 113 to 2500°F. *Tempil Corp.*

1225. Hydrogen Purifier

Serfass Corp. has published Bulletin 1159 describing a laboratory-size (10 cu. ft. per hr. at 150 psi.) purifier wherein hydrogen diffuses through the walls of a palladium-silver alloy tube acting as a barrier to all other gases.

1226. Research Equipment

Interference microscopes, particle counters, dilatometers and thermo balances described in a series of data files. *Cooke, Troughton & Simms*

1227. Picture in a Minute

Entire line of photomicrographic cameras presented in Brochure SR682, including one with Polaroid Land camera back for a copy ready in 60 sec. *American Optical Co.*

1228. Micro-Optical Pyrometer

Equipment for measuring temperatures up to 5800°F. of objects microinches in diameter explained in Catalog 95 from *Pyrometer Instrument Co.*

1229. Borescope

National Fontar Borescope described in catalog from *Englehard Industries, Inc.* It requires an opening no larger than 0.10 in. diameter.

1230. Hydrogen Analyzer

Literature available on hot-extraction equipment giving hydrogen analysis in 3 to 10 min. *Laboratory Equipment Corp.*

1231. X-Ray Analyzer

Combination equipment for either X-ray diffraction studies or for spectroscopy illustrated in data sheets from *Radio Corp. of America*

1232. Analytical Services

Spectrochemical Laboratories, Inc., has issued an attractively illustrated brochure describing their facilities for precise analysis by all modern methods available on custom basis.

1233. Optical Benches

28-p. Bulletin 156-59 describes optical and instrument benches of three types (lathe-bed foundation, single rod and double rod) and desirable auxiliaries for checking alignment or rotational movement of assemblies. *Gaertner Scientific Corp.*

1234. Fatigue Machine

Rotating-beam fatigue machine with sample enclosed in tube furnace (temperatures 200 to 1800°F.) described in Bulletin BM-2050. *Budd Instruments Division*

1235. Test Stand

Testing Machines, Inc., has issued a data sheet on a small push-pull tester and test stand, hand operated, with gages ranging from 0.01 to 25 lb.

Production and Casting

1246. Ferrochromium

6-p. folder entitled "New and Improved Simplex Ferrochrome" by *Union Carbide Metals Co.* sets forth its use in slag reduction and finishing stages in melting alloy steels.

1247. Tube Mills

88-p. book on tube mills describes equipment for converting strip continuously to welded tubing of either ferrous or nonferrous alloys in sizes from 0.25 to 26 in. *The Yoder Co.*

1248. Rolling Mills

Morgan Construction Co.'s booklet entitled "Seventy Years" recounts the history of the company since its first continuous rolling mill in 1888.

1249. Riser Sleeve

Johns-Manville, in Folder IN247A, states that a sleeve made of expanded silica and a binder, called "Ris-A-Sleev", has high insulating value and therefore contributes to soundness in nonferrous castings.

1250. Filter Elements

Stainless or aluminum elements with pressure-locking process for tight assembly are described in folder IC-801 by *Purolator Products, Inc.* Capacities from 0.5 to 24 gal. per min. Maximum particle size 15 or 25 microns.

1251. Program Controls

Bulletin GEA-6869 shows how the entire rolling cycle in a reversing hot mill can be controlled automatically for optimum production. *General Electric Co.*

1252. Automatic Forging

Bulletin 87-L-9 describes "The Automatic Production of Forgings in Closed Dies" by the "Cecomatic" process devised by *Chambersburg Engineering Co.* wherein the hot stock is struck by two moving dies driven from opposite directions by air cylinders.

1253. Rolling Mills

84-p. Bulletin 40-B details many of the rolling mills installed in recent years by *S. W. Bliss Co.*

1254. Sand Binder

Dow Chemical Co. has issued a new bulletin on "Sand Binder 230" believed to improve flow, compaction and permeability of molding sand. It retains its good properties in re-used sand.

1255. Die Caster Furnace

Data on two-chamber induction melters for aluminum die casting machines. Unique hood arrangement removes accumulated gases. *Lindberg Engineering Co.*

1256. Slitters and Coilers

Bulletin SC 55 gives the complete story of a line of slitting and coiling equipment manufactured by *Stamco.*

1257. Filters

A wide range of industrial filters of high efficiency is described in pamphlet GEO-506A by *Commercial Filters Corp.* They handle gases and liquids up to 750° F. and are made of

SELECTIVE PLATING

Production and Repair Plating
without using immersion tanks

Enables You to (1) Precision-plate selected areas economically — without disassembling components; (2) Deposit metals rapidly where conventional electro-plating is impossible or difficult. Mobile equipment takes the process to the job.

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935 East 63 Street • Cleveland 3, Ohio
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AGENTS

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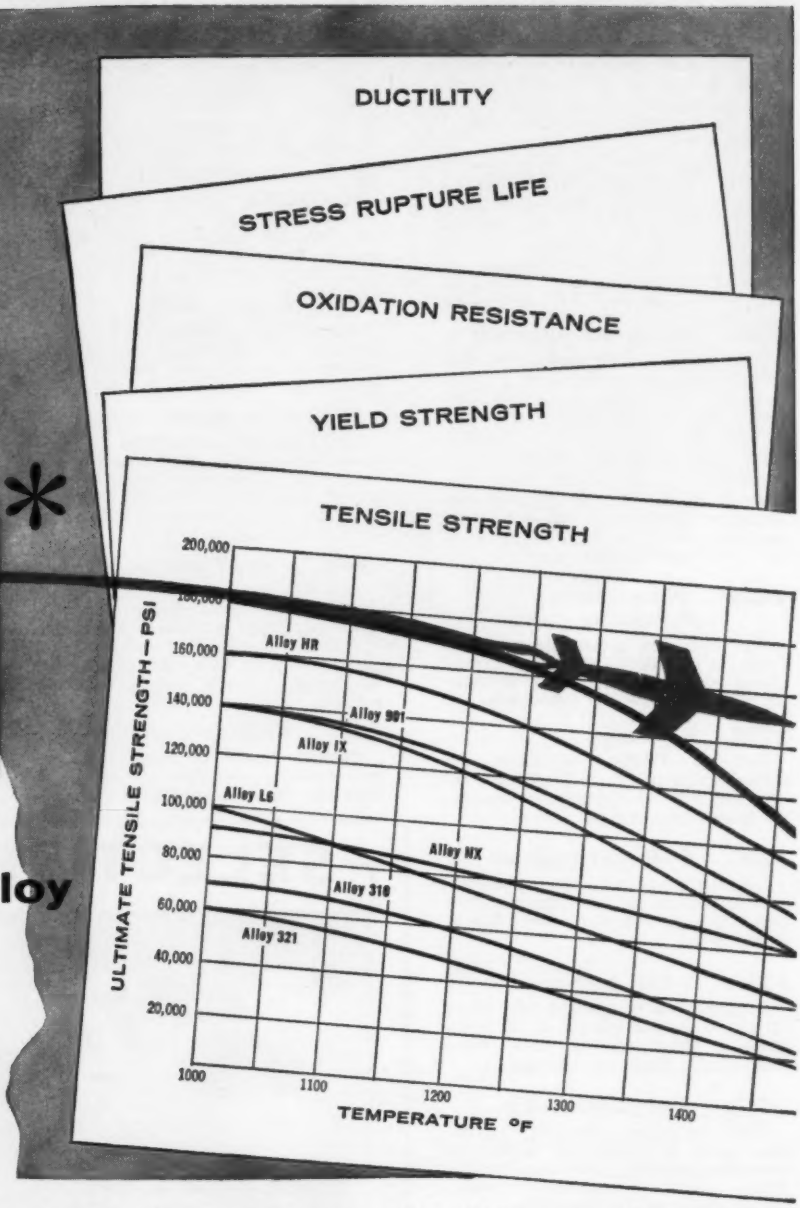
PIDDINGTON & ASSOCIATES LTD. 3219 East Foothill Blvd. Pasadena, California
OHIO METACHEMICAL, INC. 2742 Second Street Cuyahoga Falls, Ohio
D & S AVIATION CO., LTD. 671 Laurentides Blvd. Pont Viau, Montreal, Quebec

Circle 1346 on Page 48-A

HIGH on every chart:

RENÉ 41*

most dependable alloy in use today in the 1200°-1800° F range



In *all* ways, René 41 is a remarkable alloy. No other high-temperature alloy used in production today equals its tensile strength. In other properties, too, René 41 is far ahead of the field.

Also important, this nickel-base, vacuum-melted alloy is easy to work with. It's readily formable by drawing, bending, spinning — welds to similar or dissimilar materials.

Cannon-Muskegon offers René 41 in standard 36"x 96" sheets .015" to .125" thick, in smaller sizes down to .010", in bar stock up to 3" in diameter . . . foil down to .001 in thickness . . . and fine wire only .0015 in diameter.

For complete details, write for Technical bulletin No. 86.

*TM of General Electric Co.

ULTRAMET VACUUM ALLOYS

CANNON-MUSKEGON CORPORATION

2879 Lincoln Avenue • Muskegon, Michigan

METALLURGICAL SPECIALISTS

1-59

Circle 1347 on Page 48-A

glass fiber, ceramics, fuller's earth and the like.

1258. Electric Furnaces

Catalog 10 has complete technical data on 100-ton, top-charging furnaces which can melt, refine and pour a heat in 4½ hr. *Lectromelt.*

1259. Lubrication Systems

Bulletin 26-T, "Farval Centralized Systems of Lubrication" describes equipment whereby a workman at a safe point can operate a lever which delivers lubricants to every necessary point in a complicated machine. *The Farval Corp.*

Parts, Forms, Shapes

1260. Springs

"Spring Materials Digest" in its latest issue summarizes maximum operating temperatures, endurance for 10,000,000 cycles, and torsional properties of nickel alloys, copper alloys and stainless steels. *H. K. Porter Co., Inc.*

1261. Open Shapes

48-p. catalog OS-1059 shows in full-size profile some 500 open shapes, sections and moldings made from rolls and dies already in stock. *Van Huffel Tube Corp.*

1262. Malleable Castings

Data Unit 105; characteristics which give standard and pearlitic malleable iron castings their toughness. *Malleable Castings Council*

1263. Ductile Iron

Booklet "Engineering Properties and Applications of Ductile Iron" is offered by *The International Nickel Co., Inc.*

1264. Strong Cu-Ni Tube

Technical Bulletin 1411 gives data on "Hi-Y 531" alloy tubing of conventional 70-30 Cu-Ni analysis but drawn and relief annealed to 50,000 psi. minimum yield and useful operating range to 750° F. *Bridgeport Brass Co.*

1265. Impact Extrusions

40-p. booklet "Metal in Motion" discusses the advantages of impact extrusion and of aluminum parts so made ranging in size from hearing aids to 6-ft. heat exchangers. *Aluminum Co. of America.*

1266. Speed Nuts

Seventeen case histories in Bulletin 353 show how correct selection of fasteners from *Tinnerman Products'* line of 9000 varieties has cut assembly costs drastically.

1267. Hollow Mg Extrusions

Brochure on multiple hole, hollow magnesium extrusions describes practical applications in a variety of equipment. *White Metal Rolling & Stamping Corp.*

1268. Seamless Tubing

Timken Steel & Tube has data sheets and information on seamless steel tubes (carbon and alloy) of various external shapes and holes.

1269. Cap Screw Standards

Holo-Krome Screw Corp. has issued a series of five data sheets giving the 1960 standards for hexagonal socket cap screws adopted by the Socket Screw Mfrs.' Technical Committee. Form-CSN

1270. Printed Circuitry

"Anaconda Electro-Sheet" is a thin copper electroplate, bright on one side and matte finish on the other for firm bonding to the circuit board. Information from *American Brass Co.*

1271. Investment Castings

16-p. brochure argues the desirability of the Hitchiner process whereby expendable wax patterns are coated with ceramic strong enough to withstand casting stresses without outside support. *Hitchiner Mfg. Co., Inc.*

1272. Extrusions

"Cold-Prest Impact Extrusions" is the name of a technical bulletin on one of the seven fabricating methods employed by *Mueller Brass Co.*

1273. Ball Bearings

Two new series of ball bearings are shown in *Hoover Ball & Bearing Co.'s* Bulletin 112. "R series" is dimensioned in inches and is for shafts up to 1½ in. diameter. Hoover 30 series is in metric dimension and designed for very small shafts, 4 to 9 mm. diameter.

1274. Special Shapes

Illustrated booklet, "Quality Control at Standard" shows how such things as rings, shafting, gear blanks and special shapes are produced by *Standard Steel Works Division of Baldwin-Lima-Hamilton.*

1275. Improved Lock Nuts

Data sheets from *Elastic Stop Nut Corp. of America* indicates that a slight modification in the shape of the first few threads in a standard nut doubled the fatigue life of high-strength bolt by relieving stress concentrations at that region.

1276. Tubing Properties

Comprehensive chart of specifications for aircraft tubing, mechanical properties, principal applications and major characteristics has been issued by *Tube Distributors Co., Inc.*

1277. Spring Wire

Complete information on spring wire of stainless steel, phosphor bronze, nickel silver, and nickel-base alloys from *Riverside-Alloy Metal Division of H. K. Porter.*

1278. Mechanical Tubing

Bulletin TB-430 is entitled "How to Cut Cost by Using B. & W. Job-Matched Alloy Mechanical Tubing". *The Babcock & Wilcox Co.*

1279. Powder Compacts

Data on manufacture and properties of 12 iron-base and five copper-base powder metal alloys in regular production by *American Sinteel Corp.* (Bulletin FM 3020).

1280. Magnesium Boxes

Wide range of deep drawn rectangular boxes made of magnesium sheet, from 1½ in. to 19 in. in major dimension. Heights vary by sixteenths from ⅛ to 9 in. Prices and lists from *Zero Mfg. Co.*

SERV-RITE®

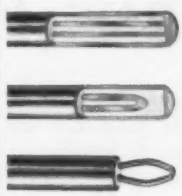
Premium Sheathed Thermocouples

(.020" to .500" O.D.)

Problems of space limitation, temperature, or pressure are solved with SERV-RITE *premium* sheathed thermocouple wire. For maximum sensitivity, accuracy and quick response, SERV-RITE will furnish the best service for your dollar.

Featuring hard-pack insulation with heavy wall construction, SERV-RITE is fully flexible and can be bent to suit requirements. In addition to a choice of junction tips, fittings and connectors, SERV-RITE *premium* sheathed wire is available in a wide range of sheath materials, bright annealed. Standard and special thermocouples are made to suit any need.

All wires used in SERV-RITE *premium* sheathed thermocouple wire are selected and matched to conform to "Special" limits of error as set forth by I.S.A. Recommended Practice, R.P. 1.3. This wire meets the strictest over-all specifications.



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for complete details, ordering data, and prices on SERV-RITE *premium* sheathed thermocouple wires and accessories.

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Manufacturers • Engineers • Distributors

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Circle 1348 on Page 48-A

FOR MAXIMUM QUALITY SPECIFY

B&W *Job-Matched stainless tubing*

B&W offers you . . .

- the stainless tube properties you need—in the right combination for ease of fabrication
- fully annealed tubes for maximum resistance to corrosion
- the benefits of a comprehensive system of quality control that assures uniformity from tube to tube—whether seamless or welded, pressure or mechanical

These are just a few of the many reasons why it pays to specify B&W Job-Matched Stainless Tubing. And remember—matching tubes to jobs assures you the *right tube,* in the *right quantity,* at the *right time.* For more information, call your local B&W District Sales Office, or write for Bulletin TB-365. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pennsylvania.

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B&W THE BABCOCK & WILCOX COMPANY

TUBULAR PRODUCTS DIVISION

Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—*in* carbon, alloy and stainless steels and special metals

Circle 1349 on Page 48-A

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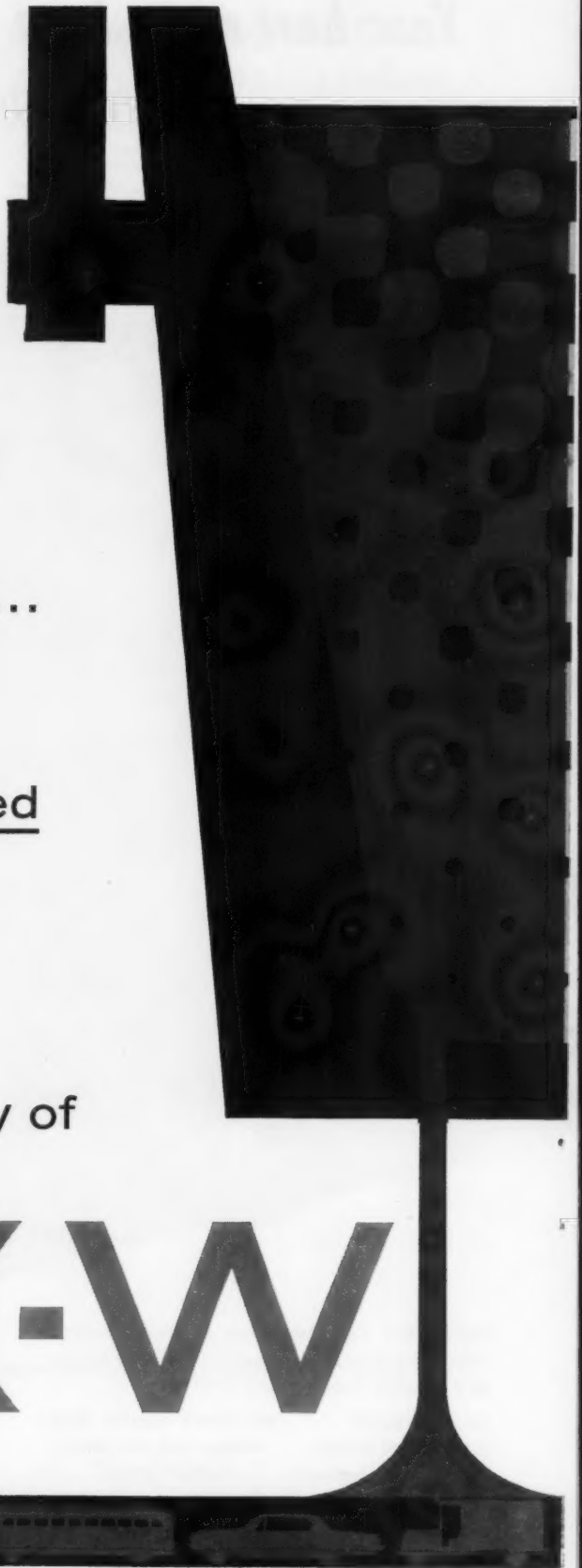

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from Great Lakes Steel...

columbium makes the

difference in fine-grained

GLX-W steel. For the

products you make,

investigate the economy of

GLX-W

Compare the benefits of GLX-W with other mild carbon steels

GLX-W gives you great yield strength—up to 60,000 psi—thanks to the finer grain structure that comes from columbium treatment. This greater strength permits designers to save up to 35% in weight, compared with ordinary carbon steels.

At the same time, GLX-W gives you the formability and weldability—with no underbead cracking—of regular carbon steels. It is recommended for a wide range of applications. Get complete details from our Product Development Division, Dept. E-13.

GLX W

GREAT LAKES STEEL
Detroit 29, Michigan

Great Lakes Steel is a Division of **NATIONAL STEEL CORPORATION**

Circle 1282 on Page 48-A

One of a series

Payoff in portable photons

Samarium-145, Samarium-153, Gadolinium-153.
Scientists at the General Motors Research Laboratories began three years ago to measure and re-evaluate the nuclear characteristics of these rare earth isotopes – their half-lives, photon emissions, thermal neutron cross sections.

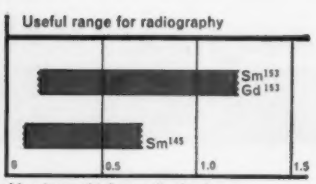
Conclusion: the radioisotopes had attractive possibilities in industrial and medical radiography, emitting almost pure gamma rays or X-rays (photons) in the low energy range of 30 to 100 kev.

The transition from research to hardware came through two key developments. First, cermet pellets were fabricated using only a few milligrams of the rare earth oxides. Then the irradiated pellets were packaged in special bullet-size holders.

The resulting small, sealed radiographic sources are now being field and laboratory tested. Two excellent applications: "inside-out" checks of hollow shapes inaccessible to X-ray tubes, and radiography of thin steel sections and low density materials such as aluminum or human bone. For example, a recent medical milestone was a chest radiograph of a living person made with a Sm^{153} source. The portable exposure unit to shield the source weighed only 18 pounds.

This isotope radiography program is but one example of the work underway in GM Research's modern isotope laboratory – work that means, through science, "more and better things for more people."

General Motors Research Laboratories
Warren, Michigan



Aluminum thickness (inches)

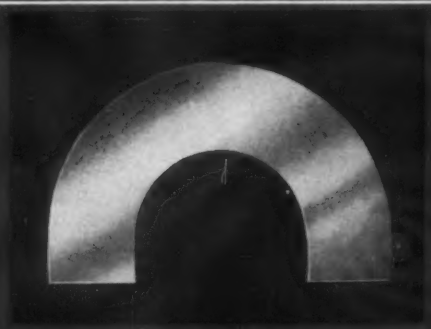
Circle 1283 on Page 48-A

Sm^{153} exposure unit.

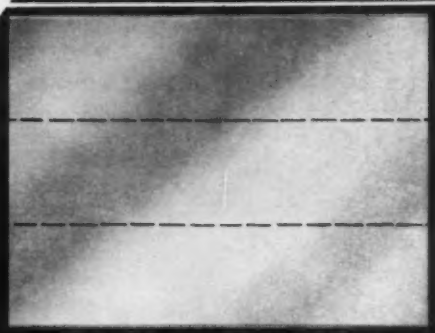
*$100.00 per part production SAVINGS.....

...with the BATH METHOD

OLD METHOD



Cutting out the blank in this titanium piece was very expensive, time consuming and wasteful.



3 titanium parts per piece instead of one.

Drop Hammer operation resulted in heavy scrap loss.

Radial Draw Forming prior to Drop Hammer operation eliminated metal distortion, greatly reduced rejects.

Finished part

Finished part

*The illustrated titanium part was not only expensive to make by old methods, but because of metal distortion, the part reject loss was tremendous. By STRETCH RELIEVING the titanium, using a Bath Radial Draw Former, part rejects were practically eliminated . . . in short, a method of forming shapes that keep their shape . . . even after heat treating . . . *Send for the plant facilities folder, it illustrates both the standard Radial Draw Forming facilities, plus a completely new series of HIGH SPEED production forming machines.*

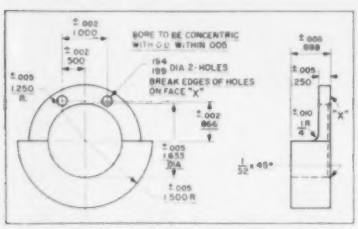
THE CYRIL BATH COMPANY

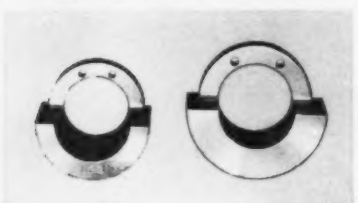
32340 AURORA ROAD • SOLON, OHIO
(LOCATED IN THE GREATER CLEVELAND AREA)
Manufacturers of Radial Draw Formers • Dies • Semi Press Brakes • Tangent Bending Sequence Presses • Press Type Brakes • Special Machines

News from CRANE on Powder Metallurgy

GRAY IRON CASTINGS VS. GRAY MATTER

Shown below are two of the 11 sizes of counterweights for crankshafts of refrigeration compressors. As the engineering drawing reveals, the tolerances are not too tight; offhand, it would appear to be an ap-





plication for gray iron casting. And that's the way it used to be made.

Today, this same part is being made from Grade B-261D powder. (This is our own pre-mix of reduced iron powder plus graphite and zinc stearate.) The change-over to powder metallurgy was made in order to reduce manufacturing costs.

Unlike the casting, the powder part requires no machining. The powder is simply compressed to a uniform density of about 6 gm/cc in a press, sent through the sintering furnace, and the job is done. There are no costly hand finishing operations, and practically no rejects.

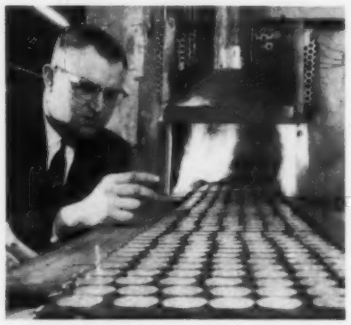
Interested in looking into the possibilities of converting some of your problems into solutions? More details are yours if you ask about *Item 1001.*

IRON ANNIVERSARY

We are celebrating our 25th year of operation right now. In place of the conventional Silver Anniversary, our theme is Iron—what else? Since we first began to manufacture metal powders as an outgrowth of some interesting investigations from a Fellowship at Mellon Institute, iron powders have been part of our business.

As a memento of the occasion, we asked one of our customers, Compacted Metals Corporation of Waukegan, Ill., to produce these medallions for us. The material of which they are made is our own Grade B-210 Iron Powder, blended with small amounts of graphite and zinc stearate. Although they bear a resemblance to coins, there was no actual coining operation involved in their production. They are simply iron powder, compacted in a 75-ton press, and sintered at 2060° F for 35 minutes.

Care to share our anniversary with us? You are welcome to one of our memento medallions; we'll see that you get one—and more information, too—if you request *Item 1003.*



Mr. Rudolph Capon, President of Compacted Metals Corporation, inspects a PM medallion just before it enters the sintering furnace.

AT THE DRAKE, SIR!

We hope you can be with us in Chicago on April 25, 26 and 27, where we will be exhibiting in the Powder Metallurgy Show at the Drake Hotel. Our station will be in Spaces 10 and 11, and we will enjoy renewing old acquaintances and greeting newcomers alike. Among the developments that have been going on in our company and our products this past year, there should be some items of mutual interest.

FOR MORE INFORMATION

Each item on this page represents only the highlights from a field or laboratory report. In most cases there is considerably more information available. If you are interested in some phase or would even like to see the complete report, drop us a note mentioning the item number.

PHYSICAL "FIT"NESS

When specs call for tough physical requirements, chances are they can be met by the judicious use of the right basic powders or mix. For instance, here are brief properties of two of our grades of iron powder and a competitive powder, compared to show changes in physicals resulting from adding 7% copper or 1% graphite, pressed at 30 tsi and sintered 30 min. at 2050°.

Many of our customers prefer to use our pre-blended grades of powder and have us blend to their specifications. This includes addition of appropriate compacting lubricants. They say they get a more uniform and reliable mix. If you would like more data on the physical changes wrought by varying combinations and amounts of additives refer to *Item 1002.*

	Iron Powder Only			Iron Powder...7% Copper			Iron Powder...1% Graphite		
	B-280	B-281	Comp.	B-280	B-281	Comp.	B-280	B-281	Comp.
Tensile*, psi	27,500	36,000	21,000	40,500	47,000	39,500	25,000	42,000	22,000
Elongation	6%	1%	8%	1%	.7%	.5%	2%	1%	3%
Mod. of Rupt., psi	68,500	72,000	52,100	77,500	98,500	74,500	59,200	94,000	48,000
Radial Growth	+.20%	−.40%	+.12%	+1.85%	+.90%	+1.80%	+.2%	+.25%	+.15%
Hardness	85	100	75	50	58	42	40	55	10
	(RH Scale)			(RB Scale)			(RB Scale)		

*Based on standard MPI test bar laboratory data for comparison only. Physical data for specific parts will vary because of structure, design and other factors.

CRANE

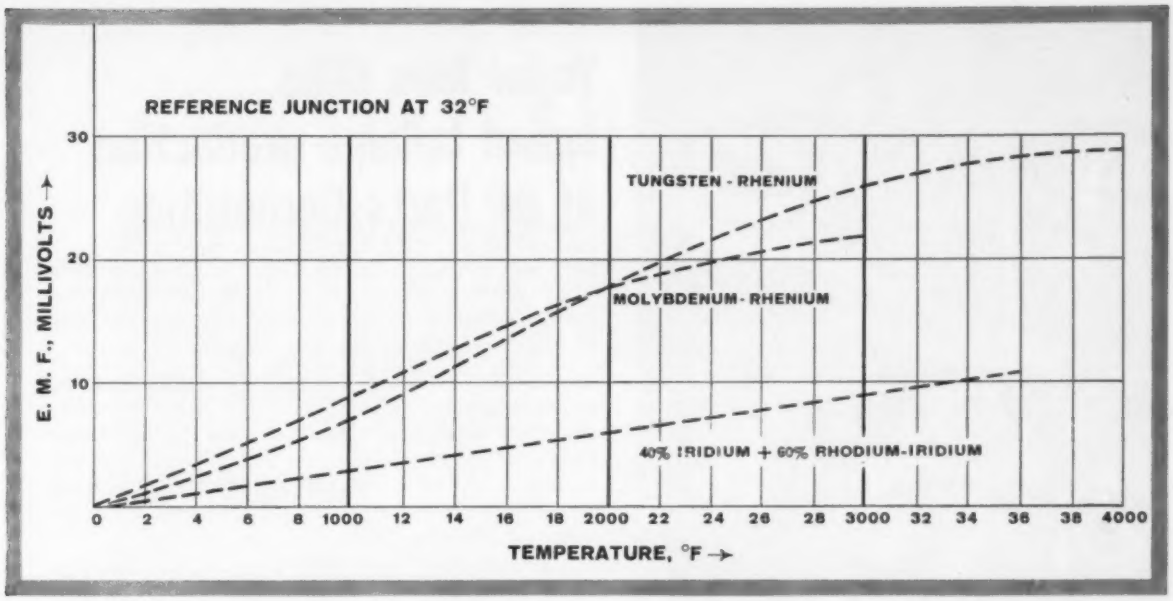
METALS DIVISION

formerly Plastic Metals Div. of National-U.S. Radiator Corp.

2960 BRIDGE STREET

JOHNSTOWN, PA.

MEMBER: METAL POWDER INDUSTRIES FEDERATION


REFERENCE JUNCTION AT 32°F
E. M. F., MILLIVOLTS →
30
20
10
TUNGSTEN - RHENIUM
MOLYBDENUM - RHENIUM
40% IRIDIUM + 60% RHODIUM-IRIDIUM
0 2 4 6 8 1000 12 14 16 18 2000 22 24 26 28 3000 32 34 36 38 4000
TEMPERATURE, °F →

Measure temperatures up to 4000°F with Honeywell Thermocouples

Precise measurement of high temperatures is almost an art. Working effectively with temperatures over 2800°F calls for an intimate knowledge of both materials and methods. Honeywell's long experience, combined with an intensive basic research program, have produced special techniques and equipment for precise measurement of high temperatures.

The thermocouples listed below—tungsten-rhenium, molybdenum-rhenium, and 40% iridium + 60% rhodium-iridium—are the best available combination of calibration stability, reproducibility and physical strength. Although the temperature-emf curves shown above are still tentative, they are based on substantial scientific studies conducted independently in several different laboratories.

Honeywell's research at the Hopkins Research Center is aimed at discovering more and more practical information on high-temperature thermocouples and passing the results on to you.

For more information, call your Honeywell Field Engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

First in Control

SINCE 1885

*HIGH TEMPERATURE ASSEMBLIES WITH PROTECTING TUBE**

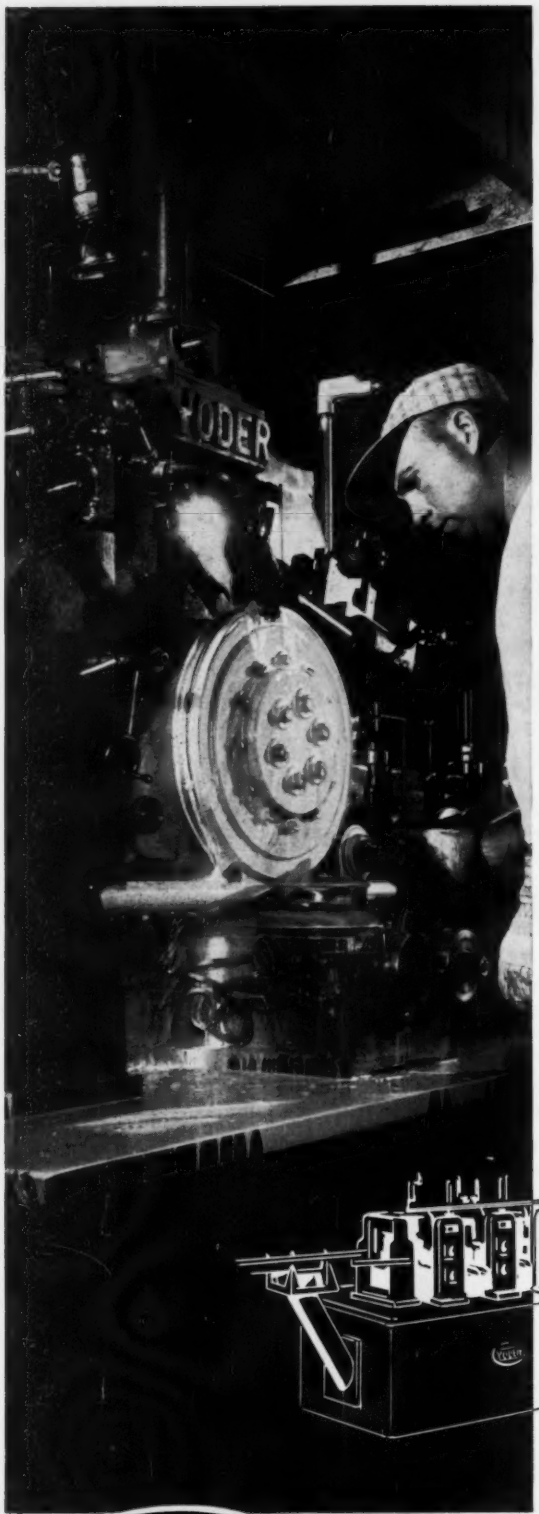
Calibration	Maximum Recommended Temperature	Tube & Insulator Material	Tube Dimensions I.D. (in.)	Tube Dimensions O.D. (in.)
TUNGSTEN-RHENIUM	3200°F	ALUMINUM OXIDE	3/16	5/16
	4000°F	BERYLLIUM OXIDE	1/4	3/8
MOLYBDENUM-RHENIUM	3000°F	ALUMINUM OXIDE	3/16	5/16
40% IRIDIUM+ 60% RHODIUM-IRIDIUM	3200°F	ALUMINUM OXIDE	3/16	5/16
	3600°F	BERYLLIUM OXIDE	1/4	3/8

*HIGH TEMPERATURE ASSEMBLIES WITHOUT PROTECTING TUBE**

Calibration	Maximum Recommended Temperature	Insulator Material	Insulator Dimensions I.D. (in.)	Insulator Dimensions O.D. (in.)
TUNGSTEN-RHENIUM	3200°F	ALUMINUM OXIDE	0.028	0.140
	4000°F	BERYLLIUM OXIDE	0.028	0.130
MOLYBDENUM-RHENIUM	3000°F	ALUMINUM OXIDE	0.028	0.140
40% IRIDIUM+ 60% RHODIUM-IRIDIUM	3200°F	ALUMINUM OXIDE	0.028	0.140
	3600°F	BERYLLIUM OXIDE	0.028	0.130

*Most assemblies available in 5", 11", 17", 20", 23" and 29" immersion lengths.

Circle 1286 on Page 48-A



Yoder Tube Mills speed tailpipe production at AP Parts Corporation

The AP Parts Corporation (Toledo, Ohio), world's largest producer of replacement mufflers and tailpipes, uses 2 YODER Tube Mills to produce more than *300* ft. of 1¾", 1⅞" and 2" tubing per minute.

According to Mr. John Grindle, Plant Engineer, the two-man operated YODER Mills are vital to the production of the entire plant. "YODER Tube Mills earn their keep daily. They are easy to set up, maintain and operate . . . the welds are clean and uniform. We depend on them for constant quality, high production and minimum downtime".

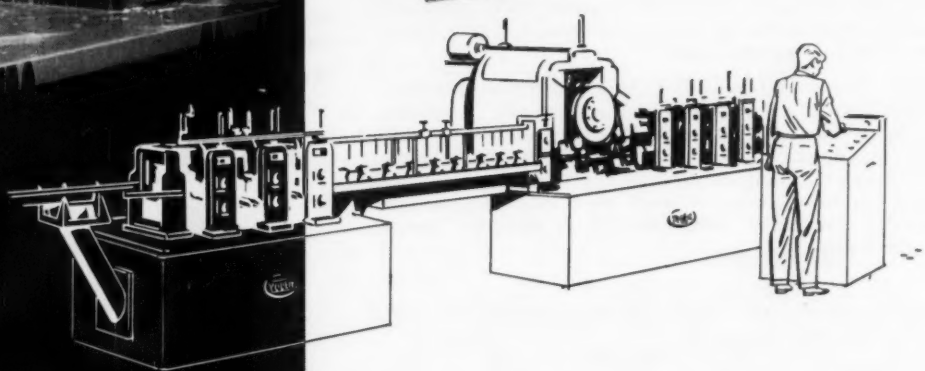
The YODER Tube Mills at AP Parts exemplify the production economies and dependability of all YODER-built equipment, whether it be Pipe and Tube Mills, Cold Roll-Forming Machinery or Slitting Equipment.

If your products require ferrous or non-ferrous pipe or tubing, from ¼" to 26" diameters, there is a YODER Mill designed to produce it economically, accurately and efficiently.

THE YODER COMPANY

5595 Walworth Avenue • • Cleveland 1, Ohio

For complete information on YODER Pipe or Tube Mills . . . write for the fully illustrated, 88 page YODER Tube Mill Book . . . it is yours for the asking.



ENGINEERING **YODER** MANUFACTURING

PIPE AND TUBE MILLS (ferrous or non-ferrous)

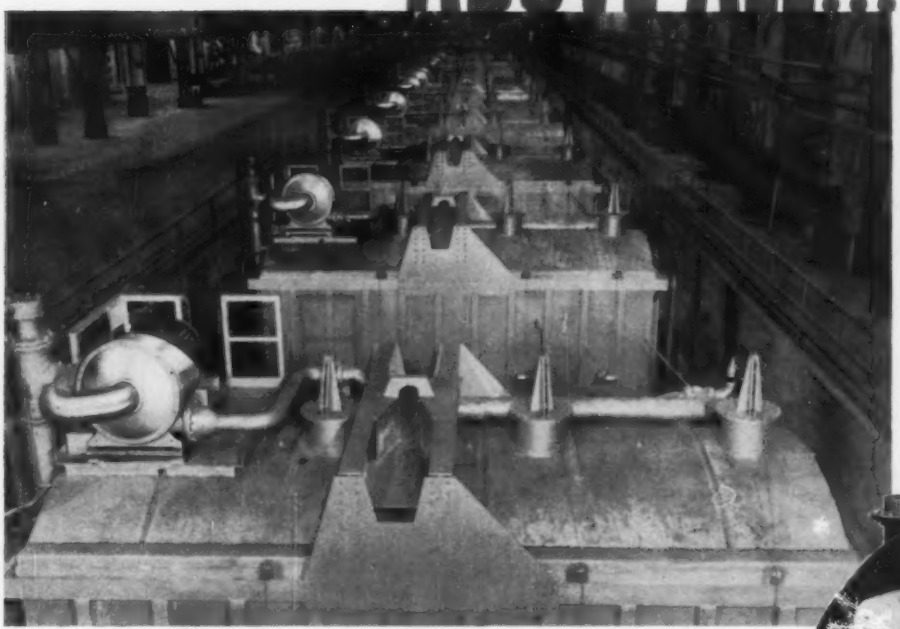
COLD ROLL FORMING MACHINES

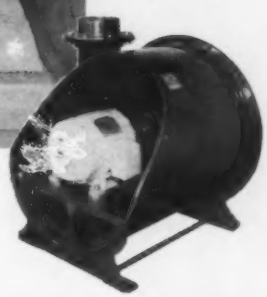
ROTARY SLITTING LINES

Circle 1287 on Page 48-A

On Controlled Atmosphere Furnaces, Too

ABOVE ALL...





Spencer blowers atop Swindell-Dressler electrically heated portable furnaces for annealing electrical steels in recirculating protective atmospheres at high temperatures.

SPENCER Blowers

Where requirements are critical, you'll usually find SPENCER blowers, preferred because of their:

COMPLETE DEPENDABILITY—Simple, rugged construction (lightweight impellers the only moving parts) greatly diminishes danger of breakdown . . . lessens likelihood of service being needed.

NON-CONTAMINATION FEATURE—Complete absence of internal lubrication (all bearings are outside of casing) means atmosphere cannot become contaminated by oil.

COMPACTNESS—Solidly built . . . with no unnecessary bulk.

ALSO MANUFACTURERS OF

PNEUMATIC CONVEYING SYSTEMS

INSTALLED VACUUM SYSTEMS

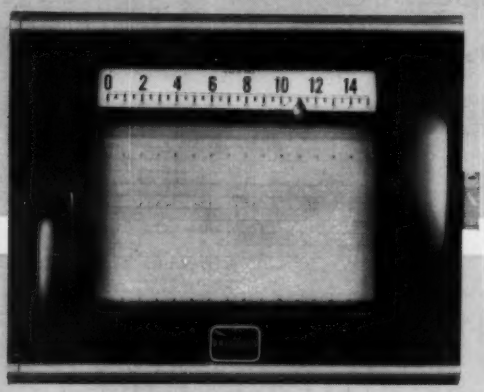
PORTABLE VACUUM CLEANERS

Request Catalog No. 126C

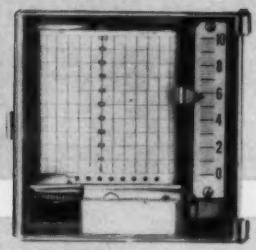
SPENCER

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

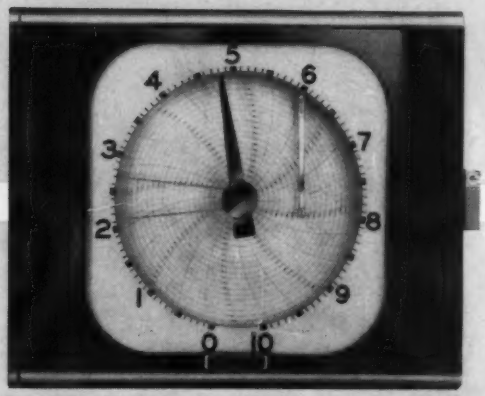
Circle 1288 on Page 48-A



Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.



Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000° F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5⅛" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U.S. Pat. Off.

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Circle 1289 on Page 48-A

WHO FORGES THE TOUGH ONES? . . . and machines and chrome plates them, too?

In producing the actuator cylinders shown above, we melted the steel, forged and precision machined the cylinders, and then chrome plated the bore to provide a wear-resistant surface. National Forge did the entire job—including final honing to an 8 RMS finish tolerance ±.001. Our extensive chrome plating work, a specialty of the National Forge Company, made it possible to complete the *unusual* requirements in this tough job, from beginning to end, all at a single responsible source.

If you have an unusually tough forging, machining, or finishing job—call National Forge.

NATIONAL FORGE COMPANY
IRVINE, WARREN COUNTY, PA.

NF-59-01

For more information on "the tough ones," and the machinery that makes them "best"—write for Bulletin NFO.

Circle 1290 on Page 48-A

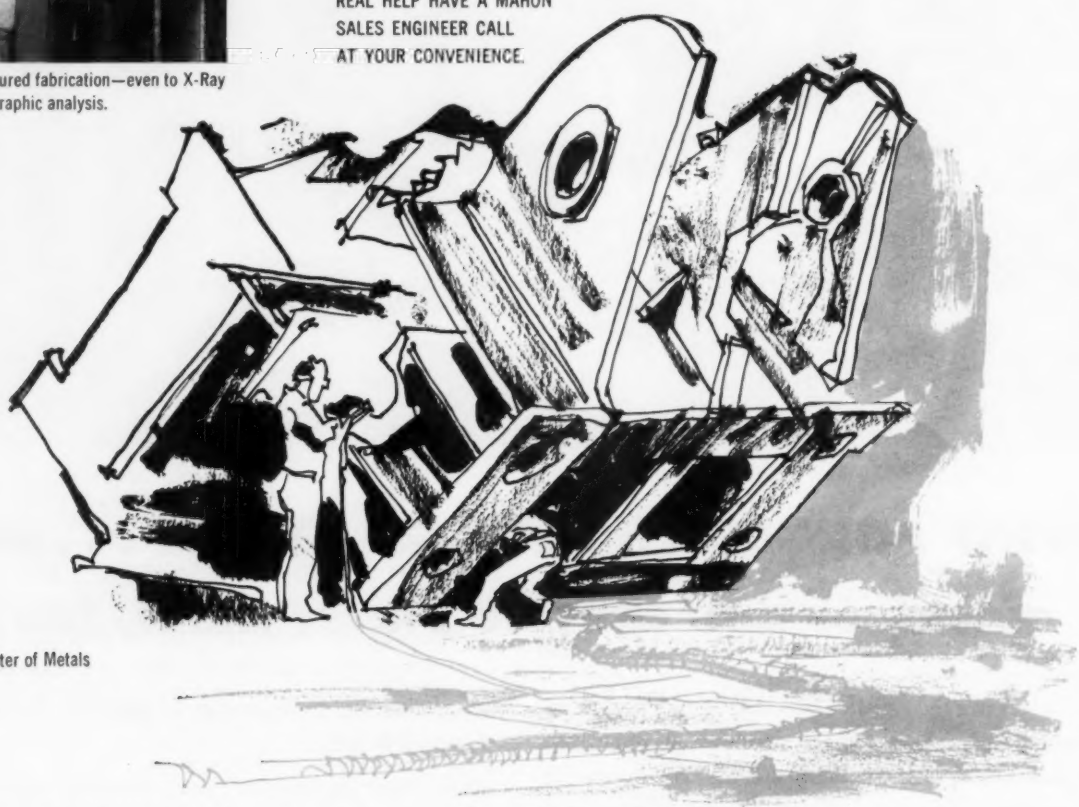
MEN WHO KNOW
FACILITIES,
CAPACITY AND
EXPERIENCE, BUY . . .

"fabrication by Mahon"

Quality-assured fabrication—even to X-Ray and Radiographic analysis.

Mahon's Steel-Weld Division has the metalworking facilities and the proven ability to take your fabricated-steel work—either mechanical or structural—from drawing to finished project. Facilities of the Mahon plants include all types of welding equipment backed by machining, assembling, testing, painting and other allied functions. Welded steel gives your designs greater strength at less weight . . . advanced techniques plus 'old-time' skill means a better product . . . and a single-source responsibility offers less delay, lower costs. For you, "Fabrication by Mahon" is an assurance of quality and service—competitively priced.
On heavy, large-dimension work in particular, Mahon is unmatched.

WRITE TODAY FOR STEEL-WELD LITERATURE OR FOR REAL HELP HAVE A MAHON SALES ENGINEER CALL AT YOUR CONVENIENCE.



Mahon-Master of Metals

THE R. C. MAHON COMPANY • DETROIT 34, MICHIGAN

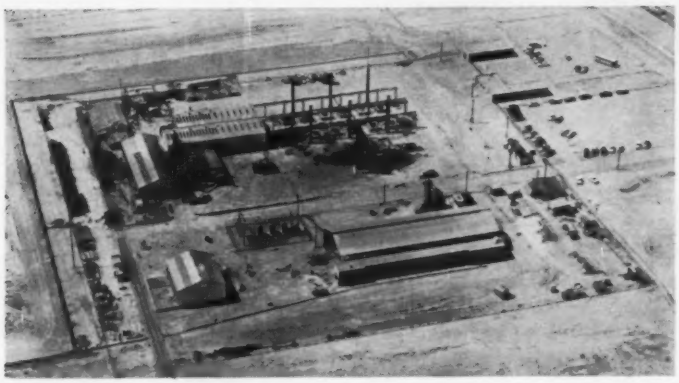
Manufacturing Plants—Detroit, Michigan and Los Angeles, California

SALES OFFICES/or Representatives Located in All Principal Cities

M A H O N

Circle 1291 on Page 48-A

GLC EXPANDS PRODUCTION WITH GRAPHITE PLANT SERVING WESTERN STATES



The GLC graphite plant at Antelope Valley, California

We are glad to inform the electrometallurgical and electrochemical industries in the Western States area that we recently acquired the plant and physical assets of Crescent Carbon Corporation in California.

Carbon and graphite users in the Western States and those overseas in the Pacific area will shortly have a greatly improved source of supply at their command.

Plans now under way at the GLC graphite plant, Antelope Valley, California, call for a substantially increased inventory of electrodes, anodes and mold stock, not only in tonnage but in a variety of shapes and sizes as well. Customers can look forward to faster service on their shipments and to closer cooperation in solving their technical problems.

Technicians from our plants at Niagara Falls, N.Y. and Morganton, N.C. are establishing the most modern production techniques at the Antelope Valley plant, so that its products will meet established GLC standards of quality and uniformity.

As these forward steps are taken, we hope to have the privilege of widening the scope of our service to customers, old and new.

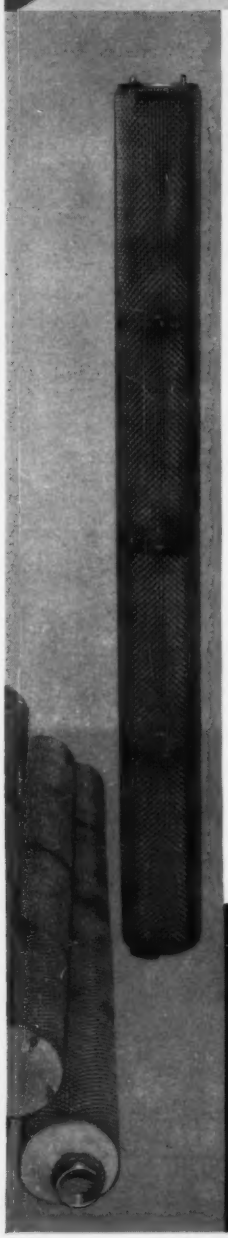
PRODUCTS ELECTRODE GLC DIVISION YOU CAN TRUST ®

GREAT LAKES CARBON CORPORATION

18 EAST 48TH STREET, NEW YORK 17, N. Y.

PACIFIC COAST OFFICE: 671F OAK GROVE AVENUE
MENLO PARK, CALIFORNIA • PHONE: DAVENPORT 3-4152

Circle 1292 on Page 48-A



Who cares about your Wire Cloth Fabrications?

CAMBRIDGE does . . .

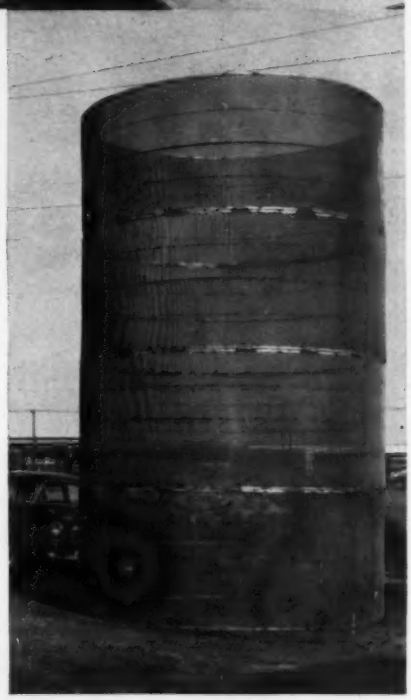
that's why you automatically get service with your order . . . whether you need dozens of midget strainers or a single giant-sized retaining screen.

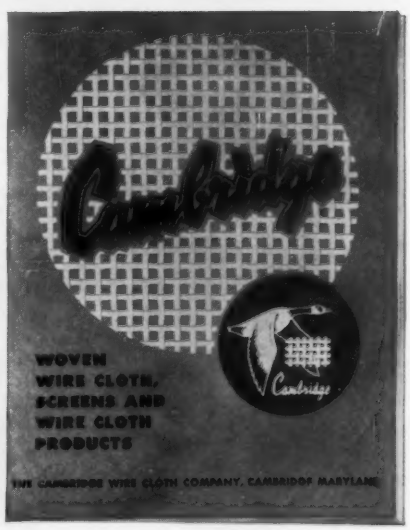
Careful, competent workmanship and constant inspection assure you of quality . . . modern machinery and accurate scheduling assure you of prompt delivery. And, a Cambridge Field Engineer follows up your order to make sure our product is giving you the best possible service. Let us quote on your next order for wire cloth fabrications. We manufacture wire cloth from any metal or alloy—including titanium—in nine basic weaves. We'll work from your prints or draw up prints for your approval. Call your Cambridge Field Engineer . . . he's listed in the yellow pages under "Wire Cloth". Or, write for FREE 94-PAGE CATALOG.

The Cambridge Wire Cloth Co.

Department B • Cambridge 4, Md.

Manufacturers of Wire Cloth, Metal-Mesh Conveyor Belts, Wire Cloth Fabrications





Circle 1293 on Page 48-A

How are they doing down on the farm?

Nowadays they're doing everything a lot easier, thanks to modern power-operated farm machinery.

And farm machinery producers have learned that their lot can be a lot easier, too, when they specify Ostuco Tubing. That's because there's no compromising with custom-quality Ostuco Tubing. Consistently you receive the exact tubing you want — the size, length, grade — with the strength and tolerances you need. For machined parts, you get our recommended rough size guaranteed to clean up.

In addition to these advantages, Ohio Seamless will fabricate tubular parts to your specification. Contact your nearest Ohio Seamless representative, or send part drawings to the plant at Shelby, Ohio—Birthplace of the Seamless Steel Tube Industry in America.

A-1958A

Complimentary Copy of new Bulletin CS60 "Ostuco Steel Tubing" sent on request.

Model illustrated built to 3.5 mm scale.

OSTUCO SHELBY, OHIO

OHIO SEAMLESS TUBE

Division of Copperweld Steel Company • SHELBY, OHIO

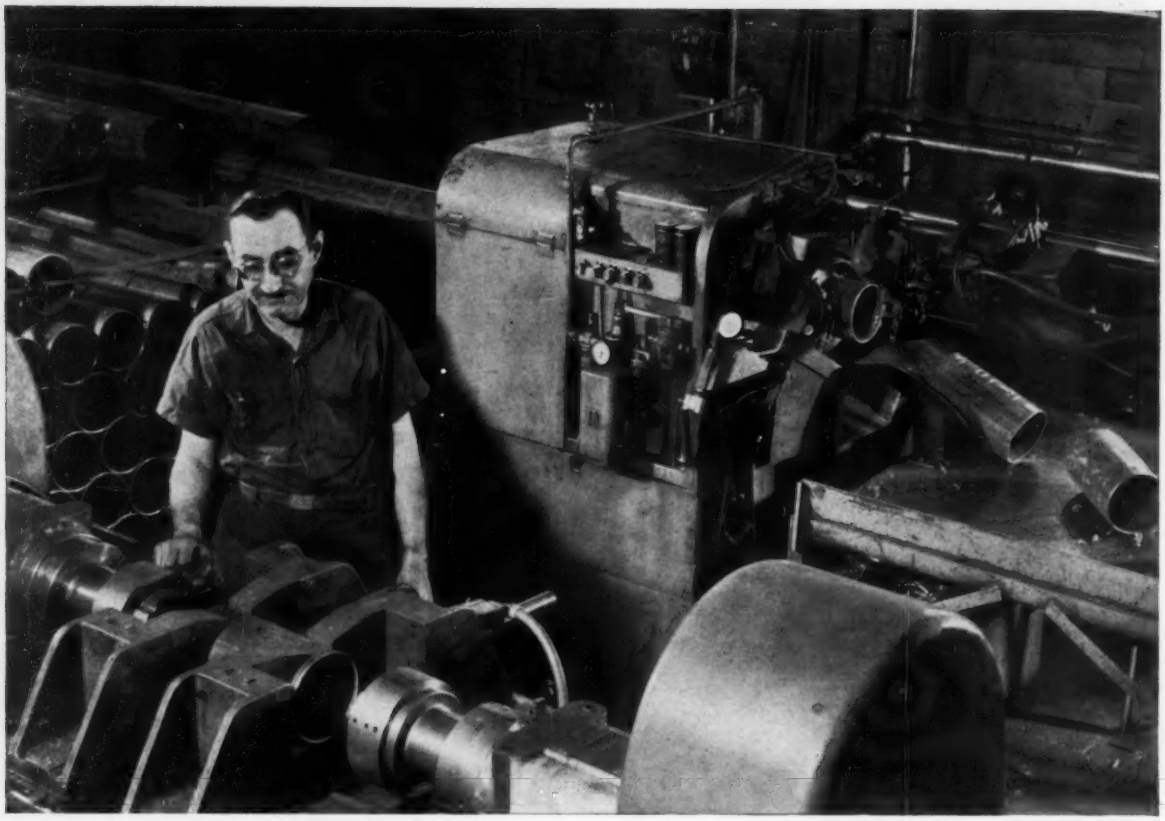
Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

Sales Offices: Birmingham, Chicago, Cincinnati, Cleveland, Dayton, Denver, Detroit, Houston, Los Angeles (Wynnewood), Miami, Moline, New Orleans (Chalmette), New York, North Kansas City, Philadelphia (Wynnewood), Pittsburgh, Rochester, St. Louis, St. Paul, Salt Lake City, Seattle, Tulsa, Wichita

Export: Copperweld Steel International Company, 225 Broadway, New York 7, New York

See us at Booth 629 Design Engineering Show May 23-26

Circle 1294 on Page 48-A



Tubing for this job must meet the most rigid specs

This manufacturer of heavy-duty idler rollers has turned to increased automation and tighter material specs to improve production. Note automatic feed and cutoff of tubing in background . . . the quick setup for double-end counterboring at the next station.

Tubing for this job must meet highest standards for uniformity of size, straightness and close tolerance of concentricity. But where do you find large O.D. tubing to meet these rigid specs? At Ryerson, of course—home of the industry's tightest quality controls.

Here you choose from the nation's largest stocks. And you're assured of consistent quality that is so important to meet the demands of automation. The more automated your production line, the less chance for visual inspection, and the more dependent you are on the consistent quality of the raw material.

So when you next need tubing or help with selection and application problems, be "Metalogical"—call Ryerson.

The type of tubing you need is here

Carbon Steel Tubing—seamless and welded, round and square, cold drawn and hot finished.

Alloy Steel Tubing—seamless rounds.

Fluid Power Tubing—Rockrite cylinder finish, seamless and welded; hydraulic fluid line; seamless and welded cylinder tubing.

Structural Tubing—square, rectangular and round.

Ledloy® 170 Tubing—fast machining, 170 sfm.

Stainless Pipe and Tubing—cold drawn seamless and welded. Also welded ornamental.

Aluminum Pipe and Tubing—all commonly used alloys and tempers.

PVC Pipe and Tubing—time-tested Ryertex®-Omicron PVC.

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Metal Progress

Vol. 77, No. 4 April 1960

NEWS • NEWS • NEWS • NEWS • NEWS • NEWS • NEWS • NEWS • NEWS •

Technical NEWS in Brief

Spray Application of Vinyl Dispersion Finishes

Finishing engineers have long recognized the virtues of vinyl resins as inert coatings for protecting metal parts. Vinyl, bonded in sheet form to steel prior to fabrication or applied by rollers as a plastisol in a continuous line, provides a tough, resilient coating which is not only corrosion resistant but attractive as well. Its potential applications are wide in the auto industry, for example, in dashboard panels, window molding and other pieces of interior trim.

The difficulty with laminated or precoated steel lies in the fact that it is coated before forming. The solution to this problem is to spray the vinyl on the part after it has been formed. One such technique has been developed by Metal & Thermit Corp. Rather than try to dissolve the vinyl in a suitable vehicle – this has proved a major problem – M & T's technique is to disperse it in a plasticizer to form a plastisol or in a plasticizer diluted with volatile liquids to form an organosol. Stabilizers, pigments, and modifiers are mixed in for resistance against light and heat, to obtain desired color, and to tailor the properties of the coating for a specific use. When parts are baked – generally between 350 to 420° F. – the vinyl dissolves in the nonvolatile carrier to form a tough continuous film.

The two types of vinyl dispersions differ in several respects. Organosols form harder coatings but the presence of volatiles limits the coating thickness to about 6 to 15 mils. They are more easily handled in conventional spray equipment, however. Organosols will probably find greatest use where it is important to reproduce the texture of underlying metal with a tough, hard coating.

Plastisols are used where more resilient coatings

SPRAY-ON VINYL DISPERSION
Heavy Coatings Are Applied to Parts After Forming

of greater thickness are desired. For example, the tub for one of G.E.'s dishwashers is now being lined with a sprayed-on plastisol. Other applications are expected in radio and television cabinets and automobile interior trim.

Estimates indicate that a 5-mil coating of spray-applied organosol per sq.ft. in volume production should cost about 14 cents. For spray-applied plastisol, the cost should average about 12 cents per sq. ft. for a coating 12 mils thick.

N.A.S.A. Reports Progress in Tungsten Research

Typical of the work being carried out on the properties of refractory metals – of prime importance in high-temperature metallurgy – is the program underway at N.A.S.A.'s Lewis Research Center in Cleveland. Here scientists are looking into the mysteries of tungsten (melting point about 6170° F.).

As part of this effort, purification of sintered and swaged tungsten by zone melting with an electron beam is being investigated. In this technique, electrons are accelerated to high velocity so as to bombard and heat a small segment of the tungsten specimen. A small layer of metal, melted by the beam, then forms and travels up the rod with corresponding movement of the electron gun. Purification of the tungsten is due to the fact that most impurity elements are vaporized in the high vacuum of the melting chamber and less volatile impurities are concentrated in the liquid zone and swept to the end of the rod. Zone melting also converts the rod to a single crystal. The combined effect is pronounced. While commercial tungsten fractures in a brittle manner at room temperature, zone-refined metal exhibits a high degree of bend ductility (see the photo below). Whether the increased ductility is the result of purification or lack of grain boundaries is an intriguing question.

Work on the effect of surface condition on room-temperature ductility of commercially pure tungsten has revealed that electropolishing can produce a seven-fold increase in bend ductility, at least in sintered and swaged rods ⅛ in. in diameter. Results indicate that tungsten is a very notch-sensitive metal, and that even very fine scratches, such as those made from light abrasion with 3/0 emery paper, drastically decrease the ductility of electropolished specimens.

TUNGSTEN SINGLE CRYSTAL
Is Ductility Due to Purity or Lack of Grain Boundaries?

Another segment of N.A.S.A.'s tungsten research deals with extrusion. Hot extrusion, for example, has proved to be a promising method for breaking down the brittle, coarse-grained structure of arc-cast tungsten ingots. Small billets have been successfully extruded up to 3800° F. at high velocity without a lubricant at reduction ratios as great as 45 to 1. The extruded metal had a small equiaxed grain structure characteristic of recrystallization. Partial recrystallization was evident in all the high-velocity extrusions, even at reduction ratios of 7.4 to 1 and temperatures as low as 3000° F.

A number of extrusions have also been made by conventional low-velocity processes using glass as a lubricant. In contrast to the high-velocity extrusions, those made at slower speed at 3100° F. have exhibited only cold worked structures.

Results of N.A.S.A.'s research on arc melting and extrusion of tungsten will be published shortly in N.A.S.A.'s TN D-269, available from the Langley Research Center.

Navy Airs Its Metallurgical Problems

You might conclude that the U. S. Navy is thinking about almost everything but floating vessels (the meaning of "navy") after sitting through the A.I.M.E. Metallurgical Society's day-long meeting on "Metallurgy in the Navy". Their worries apparently are hulls for deep-diving submarines, construction of ballistic missiles, and detection of underwater and distant objects.

T. B. Owens, U.S.N., Bureau of Ships, thinks that titanium plate, 2 in. or so thick, will probably be of much use for submarine hulls because of its excellent collapsing resistance and corrosion resistance. In hypersonic air vehicles W. S. Pellini, Naval Research Laboratory, says the materials of construction represent a constant bottleneck; for short-time service (such as re-entry periods), the shell needs two new requirements – high specific heat and high conductivity – and apparently graphite, beryllium and beryllia have the best combination.

T. F. Kearns, Bureau of Naval Weapons, mentioned a forge and rolling mill, remote-controlled in an argon-filled room, in which an "alloy sheet program" will study methods for making sheet of uniform properties uniformly. Molybdenum is the first to be studied, then columbium, tantalum and finally tungsten.

Advanced power plants were discussed by P. H. Egli, Office of Naval Research, who pointed out that the main requirements varied with the location. On shipboard, space and maintenance must be conserved. In a space vehicle, the lightest

engine per kilowatt is best. In a remote, unattended land station long-time reliability is a prime necessity. Great expectations are held for direct conversion of nuclear heat into electricity by systems akin to the familiar thermocouple. Also there seem to be some interesting possibilities of cooling (refrigeration) by the opposite action!

J. J. Harwood, Office of Naval Research, said that extensive investigations have already indicated that nickel, cobalt and chromium and their common alloys have definite limitations in really high-temperature service, although vanadium looks good for use at 1800° F. Surface protection is the key to many problems, although cermets have not fulfilled early expectations for structural use, except for flame nozzles. For that reason "superalloys" (working above 2000° F.) are getting the most attention in the Navy's research program.

Metal Statistics: Iron Powder and Zinc Recoup Losses

Last year iron powder recovered losses from the setback of 1958. Consumption, up from 22,000 tons in 1958 to almost 35,000 tons, is largely attributed to improved business conditions. Highest tonnage (54½% of the total) went to manufacturers of powder metallurgy parts. Welding electrodes and flame cutting applications accounted for about 36% of the total. The remaining 10% went into electronic and magnetic components, and into friction materials and other miscellaneous uses.

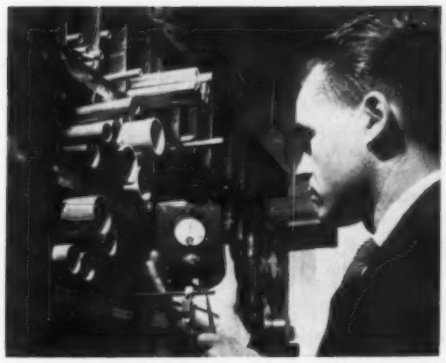
According to a preliminary survey made by the American Zinc Institute, zinc consumption in this country, estimated at 944,000 tons during 1959, also showed an increase. Influence of the steel strike was reflected in the amount of zinc for galvanized steel. Said J. L. Kimberly, executive vice-president of the A.Z.I.: "The steel strike probably cost the zinc industry bout 80,000 tons of slag zinc consumption during 1959". Major gain was in die castings which are tied closely to auto production. Improved plating techniques which give longer life to decorative auto parts may have influenced this gain. (See *Metal Progress*, March 1960, p. 112.)

Simple Device Speeds Metal Sorting

A simple, inexpensive tester, developed at the Knolls Atomic Power Laboratory, easily differentiates between such look-alike metal pairs as Inconel and stainless steel, Zircaloy-2 and zirconium, and Zircaloy-2 and hafnium. The device, developed by George Martin, consists of a standard milliammeter with two test leads – one ending in a clamp, and the other in a small carbon steel file. For testing, the clamp is attached to the unknown metal and the file is rubbed briskly against it.

The rubbing generates a tiny current (about 5 to 10 ma. for Inconel or stainless steel) which varies with the metal being tested. The milliammeter dial is calibrated accordingly.

The device works because the polarity of stainless steel is different from the polarity of Inconel, with respect to carbon steel. This also holds true for Zircaloy-2 and zirconium, and Zircaloy-2 and hafnium. Friction between the file and test sample causes a localized hot spot. The hot junction between the file and sample produces measurable current.



LOOK-ALIKE METALS SORTED
A Milliammeter, Clamp and Carbon Steel File Make a Useful Tool

Are Your Hand Tools Safe?

Tools made of manganese bronze, phosphorus bronze, aluminum bronze, commercial brass, aluminum and beryllium copper are safe for use in explosive atmospheres of gasoline vapor. Tests conducted at the Brooklyn Navy Yard also demonstrated that carbon steel, high speed toolsteel, stainless steel and monel tools are dangerous in these atmospheres. Complete report (PB-151650) is available through the U.S. Dept. of Commerce, Office of Technical Services, Washington 25, D.C.

Notes on Corrosion From S.A.E. Meeting

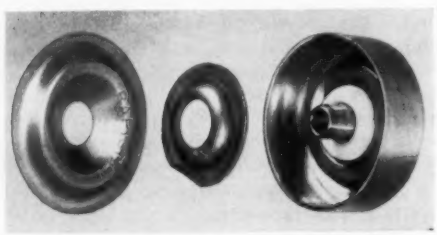
Lead contamination may be a factor responsible for increased sensitivity to corrosion of steel which has been phosphated and painted. Tests conducted at General Motors Research Laboratories, and reported by Gene L. Leithauser at the S.A.E. annual meeting in Detroit last month, show that lead is consistently present in higher amounts on the surface of steels which are most susceptible to corrosion after phosphating and painting. In experiments conducted by G.M. (more than 10,000 test panels) aimed at improving the corrosion resistance of steel, the most effective treatment was removal of the surface layer by either physical or chemical means. The finishing system which was found to be most effective in eliminating corrosion differences consists of an acrylic-type flash primer applied to the phosphated steel prior to the primer-surfacer, with no intermediate baking.

Other points were brought out by J. L. Molnar and Whitney Snyder, American Motors Corp.: The

problem of preventing corrosion in automotive bodies has been made "infinitely" greater by the comparatively recent heavy use of anti-icing materials on roads. Extremely small amounts of these materials and the moisture they attract are most damaging to unprotected steel surfaces. Said Messrs. Molnar and Snyder: "We feel that all the steel surfaces of the body, particularly the areas in the lower box section, must be protected with a system of coating good enough so that it does not depend upon a certain definite amount of ventilation for control of corrosion."

Materials Progress in Nonmetallic Bearings and Ceramic Insulation

A ring of "Delrin" – an acetal resin developed by Du Pont – replaces conventional steel balls in aluminum conveyer wheels for material handling installations involving corrosion problems. Rapid-Standard Co., Inc., Grand Rapids, Mich., which makes the equipment, states that corrosion is a problem in many conveyer applications especially in areas of high humidity, seashore locations and shipboard installations. Also, it is a problem where a conveyer must be operated under wet conditions or must be washed or sterilized frequently by steam or chemical solutions.



CONVEYER WHEEL WITH DELRIN BEARING
Acetal Resin Ring Avoids Corrosion Experienced With Steel Balls

Aluminum wheels with bearings of "Delrin" are virtually noiseless compared to steel ball bearing wheels. Weight saving of 40% is made compared to aluminum wheels with steel balls, and saving is 60% compared to steel wheels with steel balls. The aluminum used in the conveyer wheel is an alloy resistant to salt water, making the whole wheel assembly corrosion resistant.

More news of progress in materials comes from Ceramic Div. of Ipsen Industries, Inc., Pecatonica, Ill. A ceramic brick developed from an aluminum oxide formulation is expanded and then fired. This creates a cellular structure in which all cells are interconnected. The absorbent property of the ceramic material permits gas to pass through for purging. It can be operated up to 3400° F.

The developers of the material say it has numerous applications in the nuclear, metallurgical, chemical and aeronautical fields. It has found immediate acceptance as a lining for high-temperature hydrogen furnaces for vacuum processing and as a catalyst support in atmosphere generators.

From Here and There

The Russian journal *Metallurg* (No. 11, 1959) prints a very brief notice of plans for the construction of a very large blast furnace capable of producing 4800 short tons of pig iron per day. Its hearth diameter will be 32 ft. and the shaft will be 96.5 ft. high. Its inner volume will be something over 70,000 cu.ft., about 2½ times that of postwar Russian furnaces. It will have two slag notches and one iron notch, 20 tuyeres, blast pressure 1.5 to 1.8 atm. gage and temperature of 2000 to 2200° F. (1100 to 1200° C.). Mention is also made of the desirability of enriching the blast with natural gas and with oxygen, although the item does not clearly state whether either or both of these schemes is actually to be installed.

• • • •

While nuclear power reactors figure prominently in the news, a report from the Census Bureau indicates that shipments of privately manufactured items primarily for use with or for atomic energy in 1958 were valued at $148,900,000, an increase of 55% over shipments of the same items in 1957. The biggest subdivision was "radiation detection and monitoring devices", valued at $24,200,000.

• • • •

If you have been having trouble with fragile parts being damaged during barrel finishing, you may want to consider a vibratory finishing machine. It borrows an idea from truck and bus suspensions in that the work container is cushioned on a vibrating platform by inflated rubber mounts. Built by Pangborn Corp., the new finishing machine is said to turn out work up to 100 times faster and at lower cost than present equipment. Despite its fast finishing rate, the nontumbling action of the machine is gentle to fragile parts.

New Ideas for Production

Disclosed in next month's issue of *Metal Progress* will be production experience with molybdenum dies in extruding steel. Also, new ideas will be presented on precision forging and cold extrusion. Latest developments in tooling materials will be discussed by 14 experts in individual articles prepared for *Metal Progress*. These features are all part of the forthcoming May issue's special report on "Modern Tool Materials and Metal Fabrication".

Special Report on Golden Gate Metals Conference . . . *Attention is focused on high-strength steels, joining metals for high-temperature service and processing problems.*

High-Strength Steels for Missiles and Spacecraft

*Reported by G. K. BHAT**

THE OPENING SESSION ON "High-Strength Steels for the Missile Industry" was presided over by John C. McDonald and H. T. Sumsion of Lockheed Aircraft Corp. Dr. McDonald explained the immediate need for increasing the strength of the metallic components of missiles and other space vehicles to achieve the highest possible strength-to-weight ratio.

The first paper entitled "Materials and Fabrication Problems Associated With High-Strength Lightweight Homogeneous Pressure Vessels", prepared by L. L. Gilbert and J. A. Brown, Aerojet-General Corp., was presented by Mr. Brown. Stressing test methods for selecting materials for application at yield strength of 235,000 psi. (0.2% offset), Mr. Brown pointed out that two types of tests, one using an edge-notched tensile specimen and the other employing a center-notched tension specimen, are necessary to evaluate satisfactorily the notch-sensitivity of high-strength materials. The slow crack indicates ductile and the fast crack indicates the brittle characteristics of the materials in these tests. The values computed from the tests are the critical crack length (the dimension from one end of the fracture surface to the other end) and the load at the initiation of rapid fracture. The net section stress is calculated from these two values and the fracture work rate Gc is obtained in in-lb. per sq.in. for each material. These values are used in predicting the behavior of various materials in the presence of flaws and the maximum stress the material can withstand in the presence of a flaw of critical dimension.

Ultraclean Material Is Important

Mr. Brown pointed out that, whereas the above tests are important in predicting the behavior of materials which have flaws, they are of little help in describing the behavior of materials having no flaws or internal defects, or materials having minute defects of subcritical size. For fabricating reliable missile motor cases, the use of flawless or ultraclean material cannot be overemphasized. Consequently, vacuum melted materials will be the natural choice.

Charpy V-notch impact test values are useful in showing significant differences of certain

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*Fellow, Mellon Institute of Industrial Research, Pittsburgh. The Golden Gate Metals Conference was held in San Francisco, Feb. 4 to 6, 1960. A number of the papers on subjects not covered in this report will be presented in complete form in future issues of *Metal Progress*.

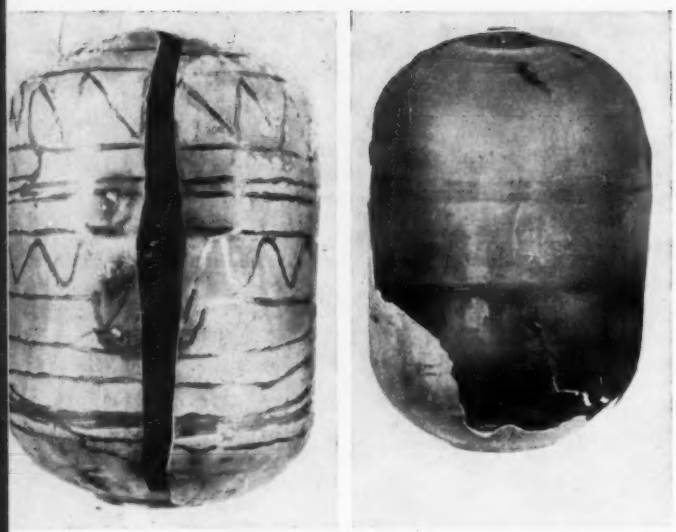


Fig. 1 — The Pressure Vessel on the Right Demonstrating a Burst Strength of 290,000 Psi. Is Superior to the Vessel on the Left Which Had a Burst Strength of Only 248,000 Psi. However, characteristics of the failure in the high-strength vessel, indicating poor resistance to crack propagation, place it in an unreliable category. Although burst strength may go to high levels in some vessels, it can also be extremely low in others because of hidden defects in manufacture. The vessels shown are typical subscale (24 in. diameter) rocket motor cases fabricated from conventional Ladish D6 steel. (Courtesy Allison Div., General Motors Corp.)

microstructures to strain rate sensitivity, although the impact values, *per se*, do not help in selecting steels for missile cases.

The behavior of subscale vessels made from various high-strength materials in burst tests was touched upon but no firm conclusions were reached. The need for correlating behavior in burst tests of subscale and full-scale chambers with laboratory tests was strongly emphasized. In addition, Mr. Brown focused the attention of research metallurgists on the following problem areas:

1. Triaxial stress conditions along the grain boundaries and the causes of embrittlement in hardened and tempered steels.

2. Effect of surface decarburization on the strength of pressure vessels and low-cycle fatigue behavior of various high-strength steels.

3. The effect of carbon, phosphorus and sulphur on crack sensitivity of weldments.

4. Tightening material specifications on chemical analysis, hardenability, inclusion rating, or cleanliness, and tolerances on surface decarburization of sheets.

Stress-Corrosion Resistance

The second paper on "Stress-Corrosion of Steels for Aircraft and Missiles" was prepared by E. H. Phelps and A. W. Loginow, United States Steel Corp. Dr. Phelps, who presented the paper, gave results of atmospheric stress-corrosion tests on several alloy and stainless steels intended for use in high-speed aircraft and missiles.

The atmospheric tests were made using bent-beam specimens ranging in thickness from 0.020 to 0.050 in., width 0.57 to 1 in. and length 4 to 7 in. The specimens were heat treated to the desired strength levels and after careful surface preparation were exposed to the atmosphere at Kure Beach, N.C. (a severely corrosive salt-spray environment), and at Monroeville, Pa. (a moderately corrosive industrial environment). The results are summarized below:

1. Low-alloy steels, heat treated to strength levels above 200,000 psi. can be susceptible to atmospheric stress-corrosion in severely corrosive environment, excluding low-alloy steels of A.I.S.I. 4100 series. Some steels are also susceptible in the moderately corrosive, semi-industrial environment.

2. Cold worked and stress-relieved austenitic stainless steels are resistant to corrosion in a severely corrosive environment. The semi-austenitic, precipitationhardenable stainless steels are generally resistant to moderately corrosive environments.

3. Generally, the time to failure for the susceptible steels increased when the stress level was decreased from 90% to 50% of the yield strength.

4. The exposure to corrosive conditions did not affect the mechanical properties of several steels.

5. Tempering some susceptible steels in the range 1100 to 1200° F. improved their stress-corrosion resistance.

6. Experiments on the mechanism of cracking indicate that stress-corrosion of 12% Cr martensitic stainless steel is the result of corrosion along an active path in the steel and is not due to hydrogen induced in the steel. Also, atmospheric stress-corrosion cracking can be prevented by certain protective coatings. Aluminum sprayed after austenitization and prior to tempering was most effective in preventing stress-corrosion. *(Continued on p. 151A)*

New Techniques Extend Potential for Brazing

*Reported by R. C. BERTOSSA**

HARRY FISK, supervisor of brazing research and development, Liquid Rocket Plant, Aerojet-General Corp., presided as chairman of the Brazing Session.

In the first presentation, George Cremer, Solar Aircraft Co., described a specially designed car-bottom furnace used for honeycomb brazing for the B-70 aircraft program. Prior to its recent cancellation, this program called for $2,000,000 worth of brazed honeycomb for each B-70 unit. A track-type movable brazing furnace is employed to produce honeycomb "beams" of PH 15-7 Mo stainless steel. These beams are 15 ft. long by 1½ ft. wide. Brazing is done by moving the furnace along the honeycomb assembly, which is stationary.

An elaborate vacuum brazing system is used for curved honeycomb assemblies of high-temperature alloys such as L-605. Techniques were discussed for brazing open-faced metal laminates, filling wide joints with gaps of 0.060 to 0.080 in. Methods for testing honeycomb panels for bond continuity by X-ray, ultrasonic and sonic means were discussed.

An interesting technique for brazing aluminum to stainless steel is based on diffusing titanium into the aluminum surface, then brazing to stainless steel with an aluminum-silicon filler alloy. According to Mr. Cremer, experimental brazing of tungsten is now in progress using a bond layer of tungsten powder in a filler metal matrix. Mr. Cremer mentioned that the filler metal used is a proprietary Solar alloy.

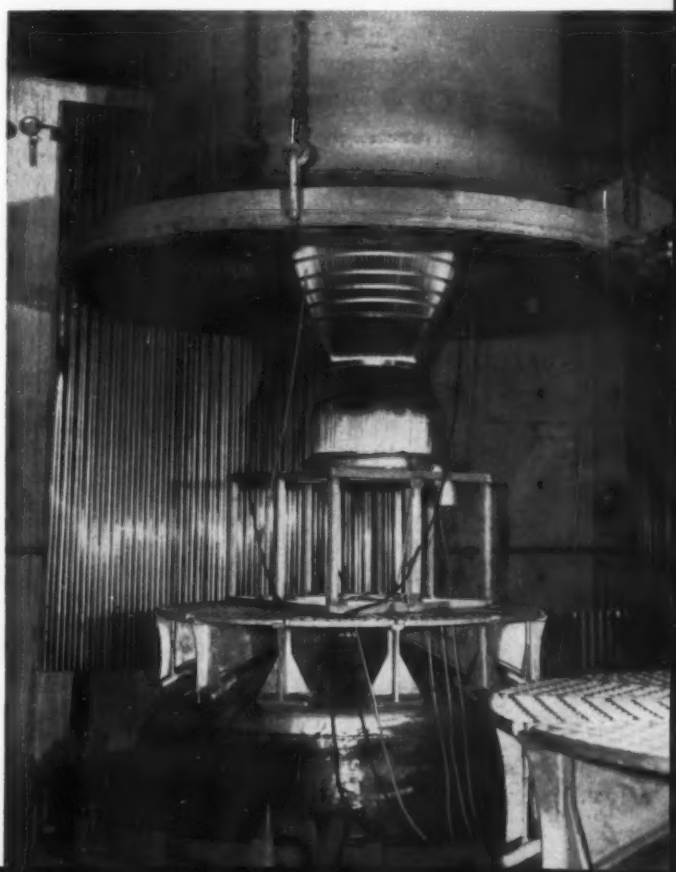
Brazing René 41

The second paper of the session, entitled "The Metallurgy of Brazing René 41", was prepared by George Hoppin III and E. Huschke, General Electric Co. In presenting the paper, Mr. Huschke stated that René 41 is a high-temperature nickel-chromium-cobalt-molybdenum alloy, containing about 3% titanium and 1½% aluminum. The titanium and aluminum additions cause the formation of dense refractory surface oxides. While this oxide film is highly resistant to further oxidation at high temperatures, it is also resistant to "wetting" and flow of brazing filler alloys in dry hydrogen atmospheres, and, to a lesser degree, even in high-vacuum atmospheres.

Embrittlement is a main source of difficulty in brazing René 41, according to Mr. Huschke.

*Consulting Editor, *Metal Progress;* Technical Director, Pyromet Co., San Francisco.

Thrust Chamber for Liquid Rocket Engine Rests on Work Base After Brazing in New Hydrogen Furnace at Aerojet-General Corp. These chambers are composed of thin-walled stainless steel tubes grouped and brazed to form a cone-shaped wall



To avoid structural damage, it must be brazed at 2150° F. maximum, which is above the solution heat treating temperature. The time at 2150° F. during brazing must be as short as possible. The brazing filler alloy used must withstand heat treatment of the part at 1400° F. after brazing, to give maximum strength to the base metal.

René 41 has been brazed with GE-J8100 (nickel-chromium-silicon) filler alloy at 2200° F. This alloy, however, is not designed to fill wide gaps and the brazing temperature is considered too high. A new filler alloy has just been developed, designated GE-J8600. It consists of 39% Ni, 33% Cr, 24% Pd, and 4% Si. Mr. Huschke stressed the fact that this alloy is completely free from boron. He stated that J-8600 alloy holds *(Continued on p. 158)*

Golden Gate Metals Conference Report

Advances in Metal Processing Solve Difficult Problems

STAFF REPORT

REAL PROGRESS IS BEING MADE in applying the plasma generator to processing of materials. In discussing the plasma device before the Conference, in a paper entitled "The Application of the Plasmatron to the Processing of Materials", Ben Lohrie, president, Plasmakote Corp., pointed out that maximum interest today is in using the plasma method for coating, spraying, cutting and shaping high-temperature materials.

Plasma for Coating and Spraying

The noble gas plasma offers pure heat up to 30,000° F. This not only exceeds the melting points, but also the boiling points, of all the elements. With such temperatures, it is possible to melt, vaporize, and spray anything.

Sprayed materials fall in to these major classifications: Barriers for heat, corrosion, and erosion protection, coatings for electrical applications, and self-supporting shapes. It is possible to spray a broad range of materials. Considerable success can be expected from most of the elements. The low-melting-point materials, such as copper and aluminum, are the exceptions, probably because the device is too hot for them. Most of the oxides have been successfully employed including thoria and urania. The stainless alloys are particularly easy to handle. Many of the carbides are routine in application, and experiments are being conducted on borides and nitrides.

According to Mr. Lohrie, plasma-sprayed materials are utilized in an impressive number of applications. Among the most important uses of the technique are to solve problems in nuclear power plants. Self-supporting shapes are being employed in many applications, such as solid-fuel nozzles.

Cutting and shaping in plasma applications is not as well advanced as spraying. However, the demand for cutting stainless steel is encouraging some development. Present equipment will need modifications to adapt it for efficient cutting. However, materials such as hard-to-cut honeycomb structure are easily handled by existing hardware, Mr. Lohrie explained.

Pre-shaping, prior to finish machining, constitutes an area of major promise. Large billets can be rough shaped in a fraction of the time conventional machining takes. Screw threads in molybdenum and tungsten have been preshaped as have other more complicated forms in these materials.

Electron Beam Melting

In a paper on application of electron beam melting to processing of materials, Charles d'A. Hunt, Temescal Metallurgical Corp., reported that the effect of this *(Continued on p. 162)*

Progress in Flame Hardening

Modern Practice of Flame Hardening

*By M. R. SCOTT**

Through suitable variations, any of the three methods for flame hardening now available (progressive, spinning and combination), can be used to harden the surface of practically any part. Unlike other case hardening methods, part size is not a limiting factor because surfaces are hardened selectively by local heating and quenching. (J2h; ST, CI)

SIMPLY DESCRIBED, FLAME HARDENING is a method for hardening the surfaces of steels and cast irons by a high-temperature flame which impinges directly on the metal surface. Cooling follows, as required. Early attempts at flame hardening were made by welders who used the only equipment available at that time – an oxy-acetylene torch and a bucket of water. This method, while crude, was effective as long as the range of uses was kept within practical limits. When it became necessary to harden parts whose areas were too large to heat evenly and continuously with a conventional welding torch, serious problems appeared. Alternate heating and quenching, induced by waving the torch to cover this larger area, caused surface checking and extreme hardness variations. Furthermore, prolonged heating and uneven quenching temperatures resulted in excessive distortion and surface decarburization.

However, the advantages of this process were fairly obvious; this led to research. In time – and after much work by a number of companies – gases, metals, equipment, and techniques were better understood. In particular, a thorough understanding of the commercially available gases undoubtedly sped development of techniques and equipment.

Today, though hydrogen, propane, city gas, and natural gas have been and are being used for flame hardening, the acetylene-oxygen combination is most popular. When burned together, these gases reach 6000° F.; the other gases, when burned with oxygen, have considerably lower flame temperatures.

Three Methods Are Available

With several types of gases available, and their analyses firmly established, the proper techniques could be developed. Eventually the progressive, spinning, and combination methods were evolved. All three methods are being used today.

As Fig. 1 illustrates, each method is easy to visualize in action. In the progressive method, the surface is rapidly heated and immediately quenched at a uniform speed. This speed generally depends on the desired depth of hardness.

For the second method, spinning, a part is surrounded by flame ejectors and heated while being spun rapidly. When it reaches the proper quenching temperature, it is dropped into, or

*Mr. Scott is president, Detroit Flame Hardening Co., Detroit.

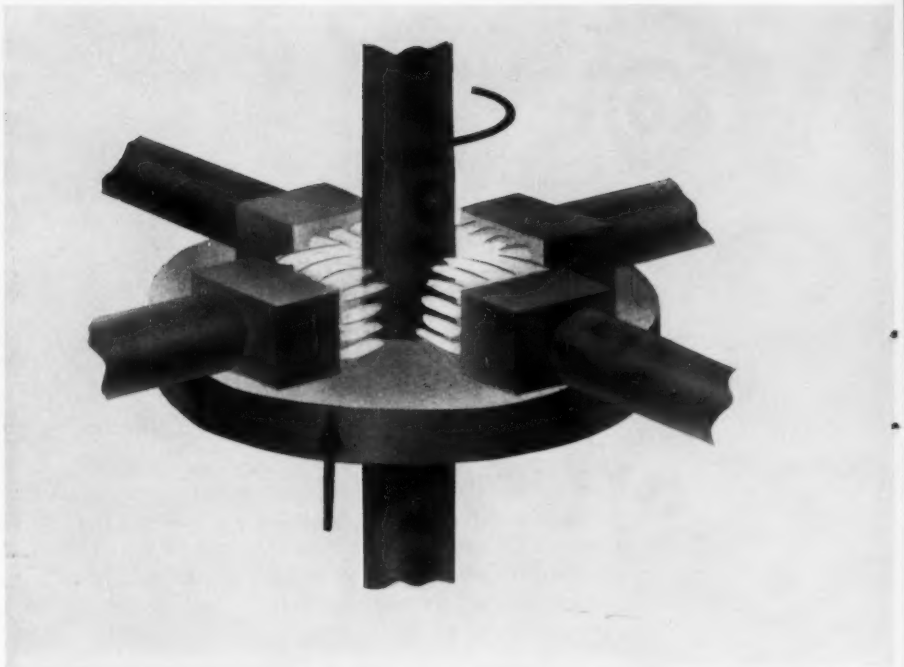


Fig. 1 – From Left, Combination, Spinning, and Progressive Methods for Flame Hardening. These systems, with appropriate variations, will answer almost any flame hardening requirement

it is sprayed with, a suitable quench solution.

The combination method, as the name implies, combines the other two techniques to provide uniform heating and quenching of a rotating part. Any of these three methods, with some variations, can be used in flame hardening virtually any part.

Materials for Flame Hardening

In flame hardening, the degree of hardness depends on the chemical analysis of the metal, with carbon being the principal controlling agent. When heating and quenching rates are accurately controlled, any ferrous material which can be furnace hardened can be flame hardened uniformly. However, flame hardening will produce a higher hardness (as compared to other case hardening methods) as the mass of the part increases.

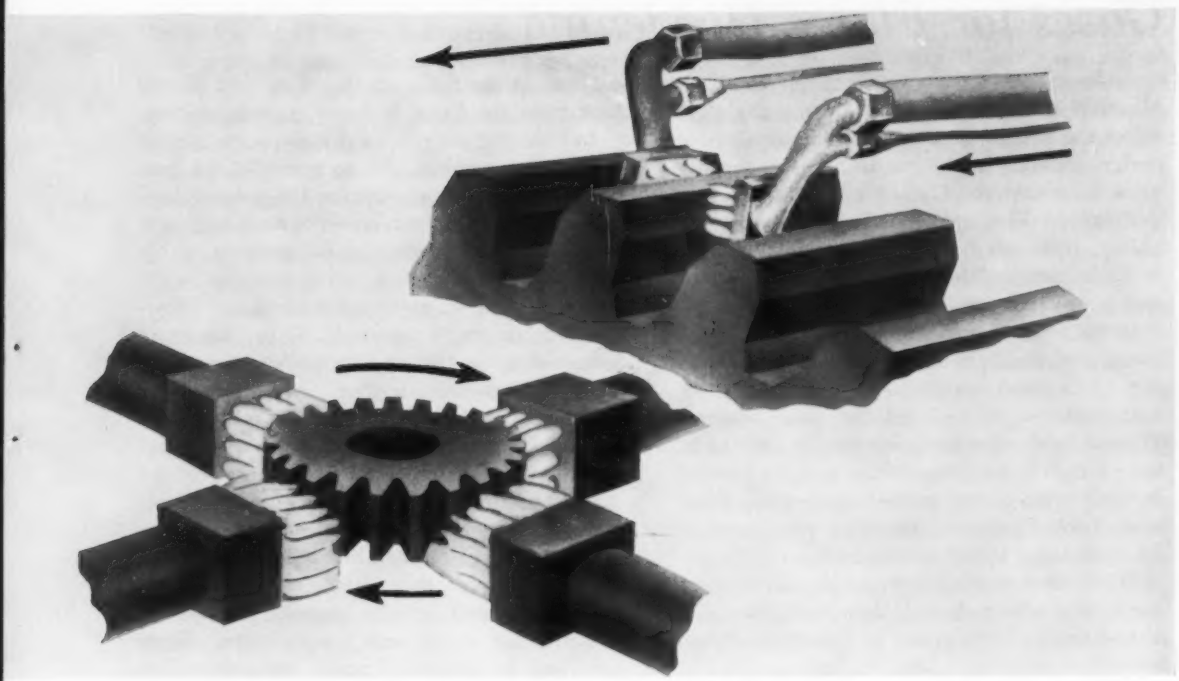
In specifying a material for flame hardening, design engineers consider availability, low cost, and machinability. With the broad variety of steels now available, designers have been able to drastically reduce fabricating costs of machine tool components without sacrificing quality. For instance, if only cost need be considered, low-carbon steels such as S.A.E. 1020 can be flame hardened to a range of Rockwell C-26 to 38 which may be satisfactory for many service requirements. Where greater core strength is required, other, more highly alloyed steels can be pre-heat treated to the desired tensile strength before flame hardening.

General Considerations

It is seldom desirable to harden an object any higher than needed for the particular application even though better hardness is obtainable. Proper selection of material should be the first consideration. For example, different materials of the same hardness may vary in other important properties such as abrasion, corrosion, or impact strength. Hardness, therefore, only partially describes a metal; it does not measure the relative resistance of different metals under varying conditions of use.

The more common elements found in alloy steels – manganese, molybdenum, chromium, vanadium, nickel, and silicon – require a thorough understanding of their effects to secure the best results in flame hardening. Generally, their effect on hardness is less important than on hardenability, a factor which can determine the depth of hardness obtainable. Undoubtedly, the intermediate zone which lies between the flame hardened case and the base metal is minimized by the use of alloys.

It has been a long-standing fallacy that only



low and medium-carbon steels could be flame hardened. Improved techniques and experience have proved that the process can benefit even the most sensitive steels. In some types of heat treating, very large masses of metal are heated and quenched, and areas with high strains are created. In irregular sections, expansion and contraction may cause failures.

In contrast, flame hardening is usually performed on an area which is relatively small. Lower expansion and contraction forces are the result. In certain applications such oil quenching steels as 4150 and 52100 can be safely flame hardened if a drastic water quench is used. In fact, a severe quench may limit the heat penetration and lessen still further the size of the stressed areas.

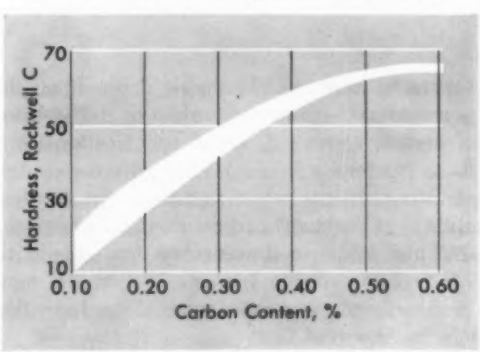
One of the interesting developments of recent years has been a better understanding of this principle as related to carburized objects. Carburizing is generally beneficial from a metallurgical viewpoint, but trouble often develops when the object is quenched. However, if the part is carburized, allowed to cool, and then flame hardened, an extremely hard surface is provided without producing the internal stresses which would occur with total immersion quenching.

All cast irons can be flame hardened with one exception – white iron. (Most of its carbon is tied up as iron carbides.) As for the others, the

Table I – Hardness Range for Cast Irons

Type	Combined Carbon	Hardness, Rockwell C
Malleable iron	0.35 to 0.85%	42 to 62
Ductile iron	0.50 to 0.75	50 to 64
Gray iron	0.45 to 0.85	40 to 62
Meehanite	0.35 to 0.90	32 to 64
Alloy cast irons	0.25 to 0.85	45 to 65

Fig. 2 – Hardness Range of Plain Carbon Steels. This graph, generally speaking, also can be used for low-alloy steels such as 8620



Gases for Flame Hardening

IN FLAME HARDENING, each potential application must be studied from many angles to select the proper equipment. Since equipment design depends on the gas to be used, the gas must be considered first. Six factors influence gas choice. They are: chemical analyses; availability; price per cu.ft.; size of section or part to be hardened; labor involved with each gas; and supplementary equipment required.

In the past, oxygen and acetylene have been considered the most efficient for flame hardening. For most applications this combination will continue to be used for three reasons: Oxygen and acetylene are readily available, have a high flame temperature, and can be used in many types of commercial equipment. However, Table I indicates that other gases can also be considered as acceptable fuels.

With the exception of hydrogen, all of them are hydrocarbons; hence, their molecules consist of one or more atoms of carbon combined with two or more atoms of hydrogen. The mixed gases (excepting city gas which has a high percentage of carbon monoxide) are mixtures of hydrocarbons and hydrogen with a small amount of other gases—some undesirable. For example, nitrogen and carbon dioxide do not benefit the flame, in that they may absorb heat from the flame to lower its temperature.

In choosing the proper gas, there are certain things to remember. As an example, the heat of combustion is no criterion for judging how well a gas will perform when burned with oxygen in a torch. Hydrogen, for instance, yields only 275 Btu. per cu.ft. while propane has a Btu. content over eight times as great. Obviously, other properties are likely to have more influence upon the heating performance than does the heat of combustion. In flame hardening, where metal is heated to an elevated temperature, the determining factor becomes what might be called the heat availability, or the amount of heat above the hardening temperature of steel or cast iron.

On a thermal basis, a heat unit of acetylene is more valuable than the heat unit of other gases because a greater percentage of it is available for use at high temperatures. Since acetylene is normally burned with about 1:1 acetylene-oxygen ratio, it yields 1419 Btu. per cu.ft. of oxygen supplied through the torch, the remaining oxygen being supplied by the atmosphere. Propane burned at a 4.5:1 oxy-propane ratio yields only 516 Btu. per cu.ft. of oxygen through the torch. The maximum temperature of the oxy-propane flame therefore is lower than that of the oxy-acetylene flame. (Flame temperature helps to determine the gas to be used in flame hardening.)

Flame intensity, another important factor, depends upon the heat of combustion and the flame velocity of the fuel gas. (Maximum

Table I – Fuels for Flame Hardening

GAS	OXYGEN-TO-GAS RATIO	HEAT VALUE, BTU. PER CU.FT.	FLAME TEMPERATURE*
Acetylene	1.45	1433	6300° F.
Hydrogen	0.28	275	5400
Propane	4.0	2309	5300
City gas	Varies	300 to 800	4600
Natural gas	1.70	800 to 1200	4600

*Burned with oxygen.

degree of hardness obtainable depends on the percentage of combined carbon or the addition of certain alloys. A broad specification for a flame hardening iron would require the control of two elements which influence the hardenability. Combined carbon should be between 0.25 and 0.85%, and silicon content should be 1.5 to 2.0%. Table I on p. 71 lists the most common irons, and the degree of hardness that can be expected.

Summary

In the past 20 years, a tremendous amount of technical data and experience in flame hardening has been accumulated. The process has gone through most of the possible misapplications to reach a position in which it does not compete with, but rather supplements, other types of heat treatment. At the same time, it has become a tool for heavy industry. Most

flame velocity of acetylene with oxygen is 1.5 times that of hydrogen and nearly four times that of propane and natural gas.) The practical effect of a high flame velocity is that a large volume of gas can be burned per unit time from a given port opening.

Availability of the gases (in other words, how they are supplied commercially) must also be considered. For example, acetylene can be obtained from generators or cylinders; propane from cylinders or as a bulk liquid; and the fuel gases from pipe lines. Availability may have an important bearing in the final selection. Gases which can be supplied in bulk form or through a pipeline have a distinct advantage over those such as hydrogen which usually can only be supplied in individual cylinders.

Costs Are Important

Consideration must be given to costs which will be involved through the use of gas. Table II shows the cost of gas required to heat 1 sq.in. of steel to approximately 1500° F. It appears that the logical choice must lie between acetylene, propane, city gas and natural gas, since each one has certain advantages in price, availability or heating time. In evaluating them, we must rely on practical engineering knowledge as well as theoretical data. Thus it is more difficult to heat a given surface of a heavy block of steel than to heat the same area of light-gage sheet. For the former, oxy-acetylene would be preferred because it will have a greater rate of heat transfer (to overcome the mass cooling effect of the steel) than any other combination. On the other hand an oxy-city gas flame could probably be used to good advantage on the light sheet since the heat transfer would be sufficient.

Selection of the proper gas also depends upon the section size involved and the heating time required. In application, if hardening can be done through automation, thereby reducing the labor factor, then the cheapest possible oxy-fuel gas should be used commensurate with quality. Some of the fuel gases with low flame propagation rates can be adjusted with a decided oxygen ratio to produce very rapid heat transfer. This adjustment, however, may decarburize the surface being heated.

Assuming that all gases have been investigated and the common ones are found adequate from the points of availability, heating time and labor involved, the prime consideration then becomes one of supplementary equipment. Acetylene, hydrogen and propane are usually supplied from cylinders and are considered medium-pressure (over 1 psi.) gases. City gas and natural gas may be low-pressure (less than 1 psi.) in many localities. In the latter situation, booster pumps may be needed to secure adequate volume by an increase in pressure. Oxygen, acetylene and propane are available in most industrial areas through various types of "bulk" system. These systems reduce the cost of the gas, eliminate cylinder handling, and assure an even, constant supply at uniform pressures.

Table II – Gas Costs

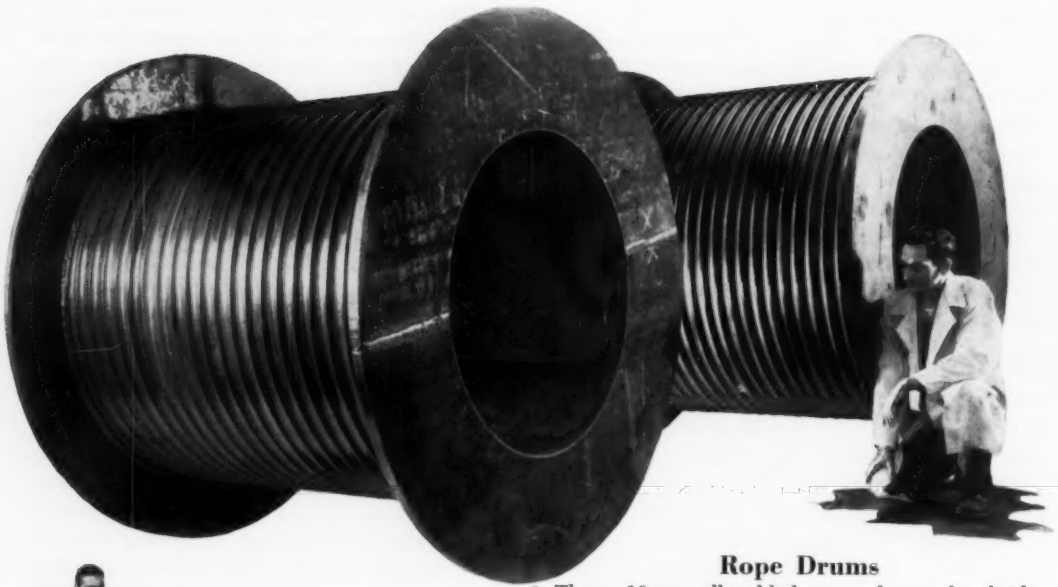
Gas	Oxy-Fuel Ratio	Basic Gas Cost*	Heating Time	Gas Cost Per Sq.In.
Oxygen	—	$0.60	—	—
Acetylene	1.1	1.60	10 sec.	$0.019
Hydrogen	0.28	1.00	30	0.014
Propane	4.0	0.16	20	0.0152
City gas	0.5	0.01	60	0.0135
Natural gas	2.0	0.01	40	0.0121

*This cost per 100 cu.ft. varies considerably depending upon location, volume used, and other factors.

heat treating operations are limited as to the size and shape of the part they can handle. Flame hardening does not have this limitation – size and shape are simply problems to be overcome by proper application of heat with suitably designed equipment. The machine tool and steel industries have been the first to employ this new concept of flame hardening. With it, they have been able to secure hardness where needed, on materials which are readily available, economical, and easily machined.

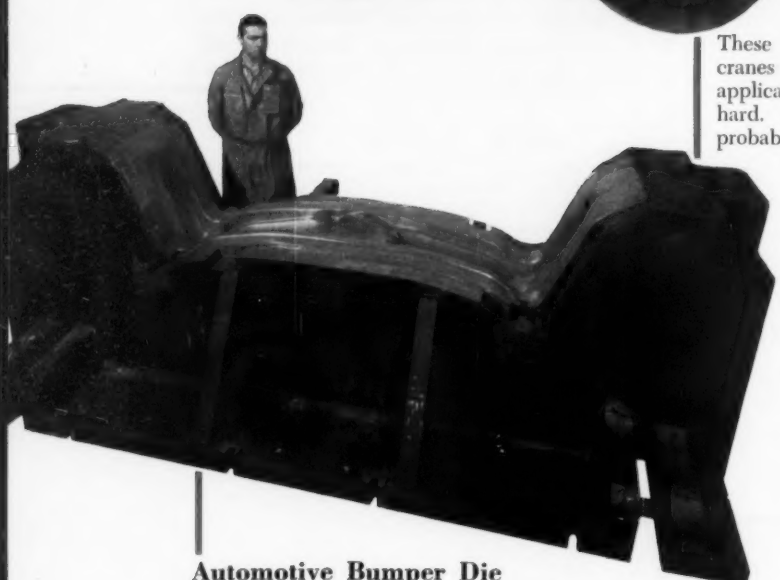
Metallurgists and design engineers have cooperated to adapt flame hardening to many of the heavy tools of industry. As the portfolio of pictures on the following pages shows, flame hardening is now being widely applied in hardening large parts for heavy equipment. Since such machinery seems to get larger and larger as time goes on, it is quite likely that flame hardening will be used more and more.

Case Histories of Flame Hardening



Rope Drums

These 10-ton all-welded rope drums for bridge cranes illustrate the perfect flame hardening application. Only the groove areas needed to be hard. Any other type of heat treatment would probably distort the drums beyond acceptable limits

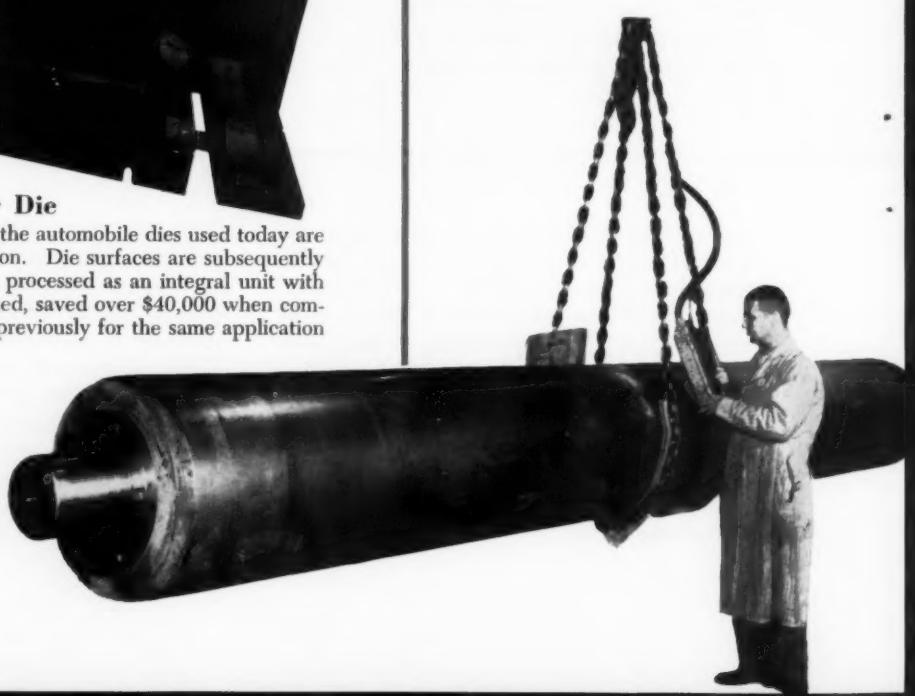


Automotive Bumper Die

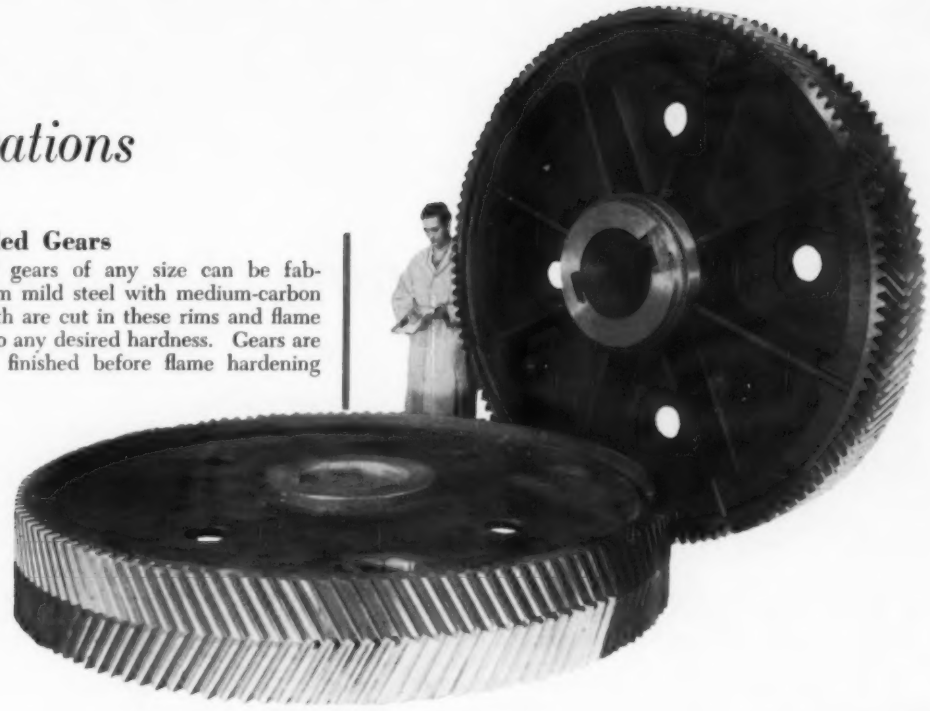
A very large percentage of the automobile dies used today are cast from gray or ductile iron. Die surfaces are subsequently flame hardened. This die, processed as an integral unit with wear surfaces flame hardened, saved over $40,000 when compared in cost to dies used previously for the same application

Roll

Today, rolls of almost any diameter or length can be flame hardened. This roll was 26 in. in diameter and 25 ft. in length. It hardened to Rockwell C-60 with less than 0.010 in. distortion in its entire length



Applications



All-Welded Gears

All-welded gears of any size can be fabricated from mild steel with medium-carbon rims. Teeth are cut in these rims and flame hardened to any desired hardness. Gears are completely finished before flame hardening

Machine Ways

In this example, machine ways are integral with the cast iron machine base. Both machining and grinding costs are reduced by flame hardening these ways

Machine Screws

Only the threads of these large machine screws are hardened so that the core properties of the base metal do not suffer. Thread hardness – Rockwell C-58 to 60

The Flame Hardening of Gears

*By JOHN T. HOWAT**

Steel gears of almost any size can be economically flame hardened providing the proper procedure is employed. This article describes some of the equipment, cost, and production problems faced by men in the field. (J2h, T7a; ST)

FLAME HARDENING, A STANDARD METHOD for treating gear teeth ever since 1919 when the process was first used in England, stays in continued popularity for many reasons.

First, its simplicity and low cost are both great advantages. Equipment may be standard oxygen-acetylene hand torches, or multiple heads in which quenching arrangements are included. Versatility is another advantage. Torches may be mounted on different types of machines for better production and better control of many types of jobs. As to heat source, oxygen and acetylene are used most extensively, though oxygen can also be combined with propane-butane and similar gases.

Many factors affect the surface temperature of the part being flame hardened. For example, size of tips (that is, area, spacing, and number of flame orifices), gas pressures, distance of flame from the work surface, rate of torch travel, and type of material being hardened are all important. The ratio of acetylene to oxygen also has an effect. As Fig. 1 shows, flame temperature reaches a maximum when approximately 1.7 parts of oxygen are mixed with one part of acetylene. Decreasing this ratio to 1.0 has little effect on the temperature, so that flame temperatures remain fairly constant over a wide range of mixtures. Below 1.0, however, a rapid decrease in flame temperature occurs. The recommended ratio is 1.2 to 1.0.

In estimating cost, the gas required to harden 1 sq.in. (the usual base) will vary from 0.2 cu.ft. of each gas, oxygen and acetylene, for an approximate depth of hardness of 1/16 in., to 0.5 cu.ft. for an approximate depth of ¼ in.

Table I gives more detailed data for estimating net costs of flame hardening. For estimating approximate gross costs, labor costs (for setting up and handling) as well as shop overhead must be added. Since these figures will vary from shop to shop, they cannot be given in the table.

Two Hardening Methods

Gear teeth are usually hardened by one of two methods. In one the torch travels along the face of the teeth; this is called the progressive method and can be applied to gears or pinions of any size. For the other method, several torches surround the gear, which is spun until the teeth are properly heated. To quench, the gear is dropped into the liquid medium or spray quenched. This is termed the spinning method; its use is limited to medium and small gears. With spinning, the time factor will range from 3 sec. to over 20 min., depending on the extent of the outside diameter and face of the gear being hardened.

Any steel that can be furnace hardened can also be flame hardened. Typical examples are given in Table II, which lists a number of alloy steels along with their hardness values

*President, Pittsburgh Metal Processing Co., Pittsburgh. This paper is based on a presentation made by the author at a session sponsored by the Metal Treating Institute in cooperation with A.S.M. at the National Metal Congress, Chicago, November 1959.

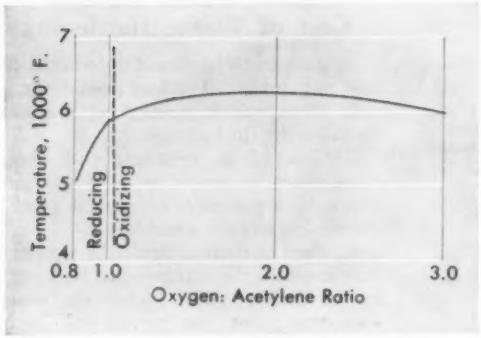


Fig. 1 – This Graph Shows That There Is an Optimum Combination of Oxygen and Acetylene for Maximum Temperature. However, in practice the oxygen-acetylene ratio can vary between 1.0 and 1.6 without a dangerous temperature drop. Below 1.0, a carbon deposit is built upon the steel surface; above 1.6, the surface is readily oxidized and burned. In the latter instance, a thick skin of overheated and coarse-grained steel is also formed

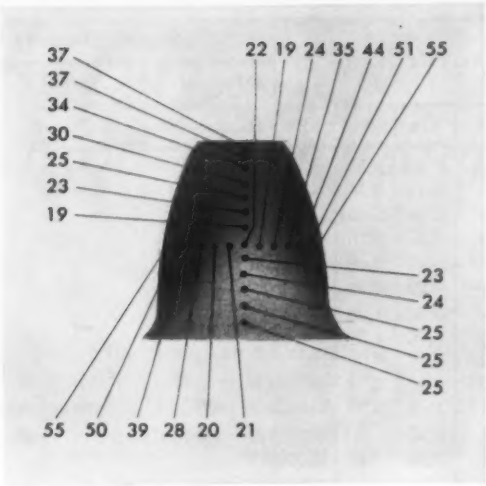


Fig. 2 – Cross Section of a Gear Tooth Illustrating Gradual Hardness Change From Surface to Core. Material: A.I.S.I. 4640, Rockwell C hardness

before and after flame hardening. To that list can be added A.I.S.I. 4340, 1141, 8742 and 4645 (after hardening, Brinell 450 to 600). For industrial and steel mill purposes, carbon and medium-alloy steels are used. In automotive or machinery gearing where high physical values are needed in the core, the higher alloy steels are used.

The operator, who should have a knowledge of heat treating practices, first checks material and hardness specifications for the work. Having done this, he sets the acetylene and oxygen regulators, and adjusts the flame so that a slight feather is apparent at the inner flame of the cone. This assures an almost neutral flame condition. The cone should be about ⅛ in. from the surface being hardened, and the torch will travel from 2½ to 6 in. per min., depending on the depth of hardness specified and the type of steel used. Flame width should be slightly smaller than the depth of the gear teeth. For the spinning method, torch tips should be set so that flames do not touch the teeth ends.

In progressing along the tooth face, speed of the torch must gradually increase as the other end is neared. (Heat builds up on the surface preceding the tip, so the time needed to obtain uniform depth of hardness is lessened. Also, the ends of the teeth should not be hardened too much.) Since physical properties of the tooth core are not altered, the correct physical values must be imparted in the gear blanks before hardening. These properties can be obtained by normal heat treating methods; the gear is usually treated to a range of Brinell 220 to 340. It is recommended that tempering temperature be as high as possible to obtain this hardness. Gears should also be preheated slightly or

Table 1 – Gas Consumption for Flame Hardening

Hardness Penetration*	Torch Travel, In. Per Min.	4-In. Tip Coverage, Sq.In. Per Min.	Acetylene Consumption†	Oxygen Consumption†
5/16 in.	2	8	0.55 + cu.ft.	0.61 – cu.ft.
¼	3	12	0.37 –	0.40 +
3/16	4	16	0.28 –	0.30 +
1/8	5	20	0.22 +	0.24 +
1/16	6	24	0.18 +	0.20 +

*Subject to variation with thickness of object heated.

†Based on using 4-in. wide tip heating 1 sq.in. of surface. Gas consumption is increased 10% by 3-in. wide tip, and 20% by 2-in. and 1-in. tips. Other sizes proportionately.

Table II – Alloy Steels for Flame Hardening

Analysis						Brinell Hardness★		
C	Mn	Si	Cr	Ni	Mo	Before Flame Hardening	After Compressed Air Quench	After Water Quench
0.25	0.34	—	0.48	3.55	—	269	—	477
0.25	0.46	—	0.61	3.70	0.42	363	—	555
0.35	0.37	—	0.56	3.55	—	255	—	601
0.60	0.70	—	0.62	0.16	—	255	—	601
0.30	0.68	—	—	3.48	—	—	—	600
0.36	0.70	—	0.20	3.34	—	—	—	585
0.40	0.80	—	0.60	1.25	—	—	—	540
0.29	0.56	—	1.16	1.52	—	—	—	610
0.34	0.58	0.18	0.79	3.06	—	255	—	490
0.41	0.68	0.25	1.44	1.72	—	258	—	512
0.33	0.54	0.17	1.29	3.95	—	302	—	460
0.42	0.62	—	0.92	—	0.27	—	—	600
0.50	0.75	—	0.95	—	0.20	—	—	660
0.40	0.75	—	—	1.65	0.25	—	415	—
0.68	0.75	0.22	—	—	0.34	—	—	712
0.42	0.71	—	1.05	—	—	—	—	615
0.40†	0.75	—	0.95	—	—	—	500	—
0.43‡	0.73	0.24	1.01	0.16	—	257	—	600
0.31	2.86	—	—	—	—	300	532	—
0.29	2.90	—	—	—	—	289	528	580
0.32	0.56	—	0.72	2.56	0.42	—	—	555
0.40	2.50	—	—	—	0.18	—	600	—
0.45	1.10	—	—	—	0.25	—	—	600
0.50	1.15	—	0.50	—	0.15	—	—	625

★Hardnesses as shown are not indicative of maximum hardness obtainable but are representative of flame hardening results using varying quenching rates.
†Contains 0.17% V. ‡Contains 0.14% V.

Facts Which Govern Cost of Flame Hardening

1. Area to be hardened determines tip size and number of orifices in each tip.
2. More gas is needed as required hardness depths increase.
3. Gases from cylinders cost about three times as much as acetylene produced by a gas generating plant (and a chargeable oxygen stand-by).
4. Steel analysis controls the temperature to which the surface must be heated for hardening. (The higher the transformation point, the greater volume of gases needed to reach this higher temperature. Alloy steels also require more careful treatment; this takes more time and gas.)
5. Simpler setups result in less time lost between each job.
6. Tip size will have a decided factor on the costs. (If too small for the work to be done, excessive gas and time will be taken to bring the surface up to proper quenching temperature.)
7. Considerable cost savings occur because sand-blasting and grinding are eliminated. (Surface is merely discolored, and distortion is usually held within the tolerances acceptable in service.)
8. The type of quenching medium used will determine the total time to harden the work (in descending order of quenching speed, water, soluble oil, oil and air).
9. A considerable saving in time and money occurs when the work can be finished with a residual heat around 350 to 450° F. (Tempering is not needed.)

heated carefully to prevent surface cracks. These may occur even without a quenching treatment. For gears, fine-grained steels are preferred because they have higher impact values than coarse-grained steels.

With flame hardening, there is no sharp line of demarcation in hardness between the case and the core as sometimes occurs in carburized work (see Fig. 2). The change is in the microstructure and not in chemical composition. Since there is no highly stressed area between the two zones, three is little possibility of spalling where they merge.

Both sides of the teeth should be heated and quenched simultaneously, since this keeps distortion to a minimum. One company also recommends that nonadjacent teeth be hardened to help keep the distortion low.

Service Failures

It should be noted here that all gears must be properly centered and aligned when installed in machinery. If not, the load can be so concentrated at either end or top of the tooth that gear teeth can fail prematurely. This extra hardness on the tooth surface will not permit the teeth to work in and take care of this misalignment. This failure should be charged to improper installation (which is responsible for more than 90% of the failures that occur in service) and not to the flame hardening. Examination of the tooth face will quickly tell whether installation was correct.

When the depth of hardness is too shallow for the pressures applied to the teeth when in service, the surface usually spalls along the pitch line. This defect may result from the flame tip traveling too rapidly along the face of the teeth, flame cones in the torch tip being too small, or the material being the wrong grade. However, when a gear is properly flame hardened and properly installed, it will last for years.

The Earliest Days of Precipitation Hardening

*By W. A. MUDGE**

During a European tour last year, one of the American pioneers in the field was able to uncover some little-known facts about the invention of the art of age hardening and the discovery of the scientific principles of precipitation hardening. (N7a, A2)

PERHAPS IT IS WORTH-WHILE to record the early history of our knowledge of the process of precipitation hardening, if only to place in perspective the contributions of several pioneering metallurgists, and to recall some important contributions to progress which are all but forgotten. Like most important advances, it started as a change in technique or practice – that is to say, a change in the *art* of metallurgy. Only later were the principles explained clearly, and on this scientific foundation progress was rapid. It is not too much to say that the quenching of steel, practiced by smiths since time immemorial, is a special example of the hardening of metals, applicable only to those comparatively few alloys which form martensite when an unstable solid solution is cooled. On the other hand, hardening by a dispersion of precipitated particles – either by mere aging or during a short and moderate reheating – is the much more general hardening phenomenon.

These versatile age hardenable alloys use annually as much as 700,000,000 lb. of aluminum, 25,000,000 lb. of magnesium, 7,000,000 lb. of nickel, and sizable amounts of many other metals. Depending upon the alloy, they provide the desirable characteristics of high strength with lightness, or of high strength with resistance to corrosion at elevated temperatures. Without them – particularly the alloys of aluminum and of nickel – gas turbines and jet aircraft, as we know them today, would not exist. And the end is not yet. We may confidently expect the day when age hardenable alloys can be *designed* for especially severe services. Thus for creep resistance we will have an alloy which will gradually harden (strengthen) as it serves at high temperatures.

But to an account of the earliest days of precipitation hardening:

Paillard

Contrary to popular belief for half a century, precipitation hardening ("age hardening", as it was known at first) did not begin with Alfred Wilm's observations and experiments with duralumin[24] during 1906 to 1909 when he was at the Zentralstelle für wissenschaftlich-technische Untersuchen at Neubabelsberg, near Berlin. It was actually known, patented, and used approximately 20 years earlier by a Swiss manufacturer, Charles Auguste Paillard[17] of Geneva.

Paillard was granted German patent No. 38,445 entitled "Palladium Alloys", and British patent No. 6367, "Improvements in Metallic Alloys", both dated May 11, 1886, to describe and protect his invention of palladium-copper-silver alloys containing small percentages of one or more of the following metals: gold, nickel, iron ("steel", the patent says), rhodium, and platinum. The alloys were used for hair springs and the compensation balance. They were malleable, strong, nonmagnetic, corrosion resisting, and possessed "the property of acquiring hardness and elasticity by the process used in hardening cymbals and gongs, that is to say,

*Retired; formerly Assistant to the President, International Nickel Co., New York.

heating to a dull red heat, and then cooling slowly".

The two patents describe nine alloys having the following chemical compositions: 45 to 72% palladium, 14.5 to 26% copper, 3 to 25% silver, 0 to 5% gold, 0 to 5% nickel, 0 to 3% iron, 0 to 1% rhodium, and 0 to 1% platinum.

The claims in the German patent cover a palladium alloy which is "hardenable, nonmagnetic, and corrosion resisting"; those in the British patent define a palladium alloy which is "nonmagnetic and unoxidizable". In other respects the language in the two patents suggests that the text of the British is a translation of the German one. But the omission of the word "hardenable" in the British patent was important; it suggested either prior art or inaccuracy in translation. This was investigated by the present author recently at the British Patent Office but without positive results because all records or correspondence regarding patents granted earlier than 1925 (Patent No. 263,501) have been destroyed.

During this search, however, a second British patent[18] by Paillard was found. It is No. 8730 of July 3, 1886, entitled "Improvements in the Manufacture of Compensation Balance Wheels for Watches and Chronometers". It is directed to the use of the alloys described in No. 6367 for the manufacture, by casting, of compensation balance wheels for watches and chronometers. It states, "It is desirable, in order to give hardness, to heat the balance in the same way as for tempering hair springs." There is one other reference to Patent No. 6367 in the specifications. (This was common procedure.) Because Patent No. 6367 contains no similar reference to any earlier work, it may be concluded that no prior art was known. No record of a German patent similar to this British patent has been found.

Efforts to learn more about Paillard's work in Switzerland have not been successful. However, there is no doubt that Paillard produced and used one or more precipitation hardenable alloys which could be hardened after fabrication by a single thermal treatment, without intermediate quenching, similar to the procedures used widely today for the copper-beryllium and the nickel-base alloys.

Wilm and the Duralumin Alloy

The above statement of prior achievement should not in any way disparage Wilm's excellent work on aluminum, 20 years later. No criticism of any kind is intended nor implied. The only purpose of the writer is to trace an epoch-making metallurgical accomplishment

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from its roots in the past, at a time when dissemination of new scientific and technical information was much less prompt and efficient than it is today.

Wilm's observation of the aging of duralumin, the chemical composition of which he had patented previously, is the best "Boy Meets Girl" story in metallurgy. In his laboratory at Neubabelsberg, where he was investigating the improvement of mechanical properties of aluminum alloys and the suitability of the alloy called "duralumin" for light armor[25], specimens had been quenched preparatory to hardness testing. Wilm was an enthusiastic sailor, and this Saturday morning, he told his assistant, Jablonski, to make the hardness tests, and that there would be no more work that day. Very shortly after Wilm had departed, Jablonski left for a weekend in the country. He played hookey and the hardness tests were not made until the following Monday morning. The assistant was then surprised when he obtained hardness values considerably higher than usual and he told Wilm the entire story. Wilm, a good scientist, realized the significance of the new data. He quenched additional specimens of the alloy and tested them hourly and daily. Each day the specimens had greater hardness, and nothing was done to them except to move them back and forth from a table to the testing machine.

Thus was age hardening discovered, as Wilm himself has told the story and as others have repeated it.[8, 23, 31] The discovery was patented[26], described later[24], and has been acclaimed widely.[3, 10, 23, 31] The alloys were used in German aircraft in World War I and thus came prominently to the attention of metallurgists in the Allied nations. Certainly, Wilm knew nothing about Paillard's alloys or he would have investigated accelerated aging more fully, either at Neubabelsberg or later during his work at the factory of Durener Metallwerk.

Moore and Etheridge

About a year after Wilm's paper was published, but before it had been read by either of them, Harold Moore and A. T. Etheridge at Woolwich Arsenal in England observed intense age hardening in aluminum-copper and in aluminum-copper-zinc alloys which contained magnesium.[12] Because of the confidential nature of their work for the World War I effort, this information was not published until 1921 when Mr. Moore contributed it as a discussion[13] to the Eleventh Report of the Alloys Research Committee. He then gave data for aluminum alloys containing up to 3.5% copper, up to 11.5%

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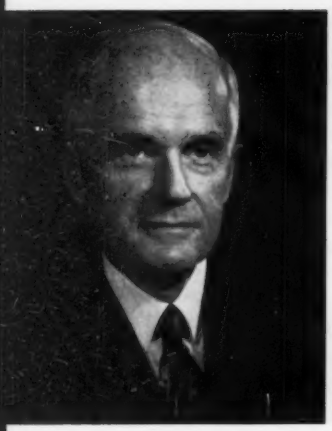


Paul D. Merica

E. M. Wise

Harold Moore

Alfred Wilm

zinc, up to 0.15% silicon, and 0.15 to 6% magnesium, the hardness numbers of which were increased by 60 to 140% after aging 14 days at room temperature after quenching from 450° C. (840° F.). Magnesium without silicon did not produce this effect. Unfortunately, the destruction of the original records in the Woolwich and Moore files in the early air raids of 1940-1941 prevent me from giving further information of this independent discovery, although Moore has frequently acknowledged that Wilm's work was earlier than his[12].

Merica and the Explanation

However (and again with all due recognition of and respect for these early discoveries), it was Paul D. Merica and his associates R. G. Waltenburg and Howard Scott at the National Bureau of Standards in Washington who uncovered the possibilities of precipitation hardening when their epoch-making paper[9] was published in 1919. Paillard, Wilm, and Moore each had observed and used the phenomenon as an *art*, but Merica and his associates made it a science. The Americans explained it in such simple terms that metallurgists could use the principles for building new alloys.

The interval of eight years between Wilm's and Merica's publications is another example of inadequate distribution of technical information. Shortly before his death in 1958, Dr. Merica told the present writer that during his postgraduate study in 1912 to 1914 at the University of Berlin, only about ten miles from where Wilm was working, he had never heard of Wilm nor of his work, and it was not until later, when he was at the Bureau of Standards, that he learned about Wilm's paper, read it, and found it so interesting that he decided to investigate the phenomenon which it described.

Design of New Alloys

E. M. Wise, then with the Wadsworth Watch Case Co. of Dayton, Ky., and later for many years with the International Nickel Co., produced the first "tailor-made" age hardenable alloy[27] on Feb. 23, 1922, using the principles set down by Merica, Waltenburg and Scott. It was a silver-base alloy containing 4% aluminum and 3.5% copper, and was designed to be age hardenable and to provide a harder sterling silver for belt buckles. Quenching in water from 650° C. (1200° F.) and then heating (hardening) for 30 min. at 325° C. (615° F.) increased the yield point of the alloy from an original 19,280 to an eventual 69,300 psi. At the same time, Wise hardened and strengthened sterling silver, containing 7.5% copper, from 19,680 to 30,000 psi. yield point, using the same thermal treatment. Detailed information of this pioneer work was published six years later[28], but only as a commentary on another paper. It was printed in fine type, and who reads the fine print?

After this real pioneering work, there were discoveries and disclosures in rapid succession of the hardening of copper with aluminum by Read and Greaves[20], with tin by Wise[29], and with silicon by Corson[1] during 1920 to 1923; the hardening of gold by Wise[30] and of magnesium by Jeffries and Archer[6] in 1922; the hardening of nickel by this author[14, 15], and of zinc by Peirce and Anderson[19] in 1924; and of many other metals[2, 4, 7, 10, 16, 21, 22, 23].

The matter is only beginning.

World's Largest Vacuum Induction Furnace

*By J. W. BYRNE**

A description of the construction and operation of the nation's first 5000-lb. vacuum induction furnace is given here. Several engineering innovations help to make this a versatile, capable installation. (W18a, 1-73)

THOUGH VACUUM INDUCTION MELTING became known at least 100 years ago, actual large-scale development had to wait for the proper equipment to be devised. Real production was first accomplished by Rohn in World War I. Induction furnace design made headway between 1920 and 1940 and suitable vacuum systems became available during World War II. Developments in vacuum induction melting then came rather rapidly, until the middle 1950's, when the industry found itself limited to a furnace size which could melt only 2000 to 3000 lb. at one time.

To increase capacity and maximum ingot size, the Metals Div. of Kelsey-Hayes began to plan a 5000-lb. furnace in early 1956. By November, a manufacturer† had been selected, preliminary drawings approved, and construction was started.

An artist's cutaway conception of the furnace, which has three-chamber design to permit semi-continuous casting, is shown in Fig. 1. The three chambers are separated by two 30-in. diameter vacuum valves, both of which are visible in the photo. As can be seen, molten metal flows from the crucible along the refractory-lined runner to the tundish in the mold chamber. Since this runner is movable, the valve can be closed at any time during the melting cycle.

Additions and new charges can be introduced from the twin vertical cylindrical chambers at the rear of the melting chamber. From these containers, an internal screw feeds measured charges to the pot. Any size, from small pellets of nickel up to scrap hot tops, can be added. In this furnace, cycling of any kind is eliminated; the time required to freeze a 5000-lb. ingot provides more than enough time to prepare the furnace for a new heat. Every size of ingot between 200 and 5000 lb. can be poured in the new furnace, and both molds and tundishes can be rotated when pouring.

Tank Tilts to Pour

Figure 2 illustrates the major mechanical innovation in our 5000-lb. furnace. That is, crucible and tank are a unit and can be tilted together. This type of design is likely to have much influence on future work by manufac-

*Project Engineer, Metals Div., Kelsey-Hayes Co., New Hartford, N.Y.

†The pumping system was built by F. J. Stokes Co., and furnace design and construction were handled by ASEA, Vasteras, Sweden, following the initial concept and design by the Metals Div.

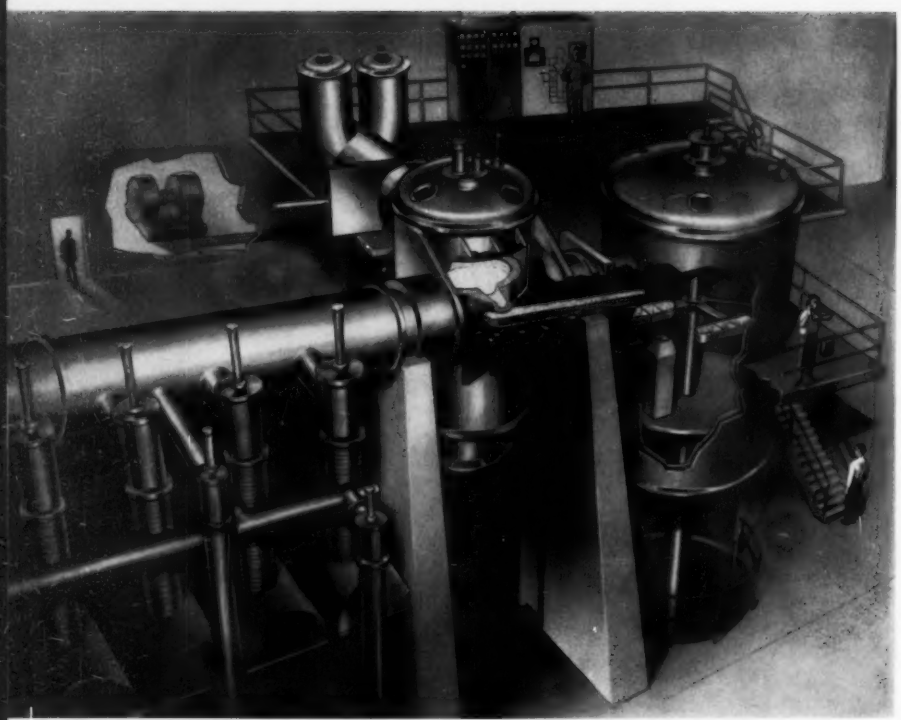
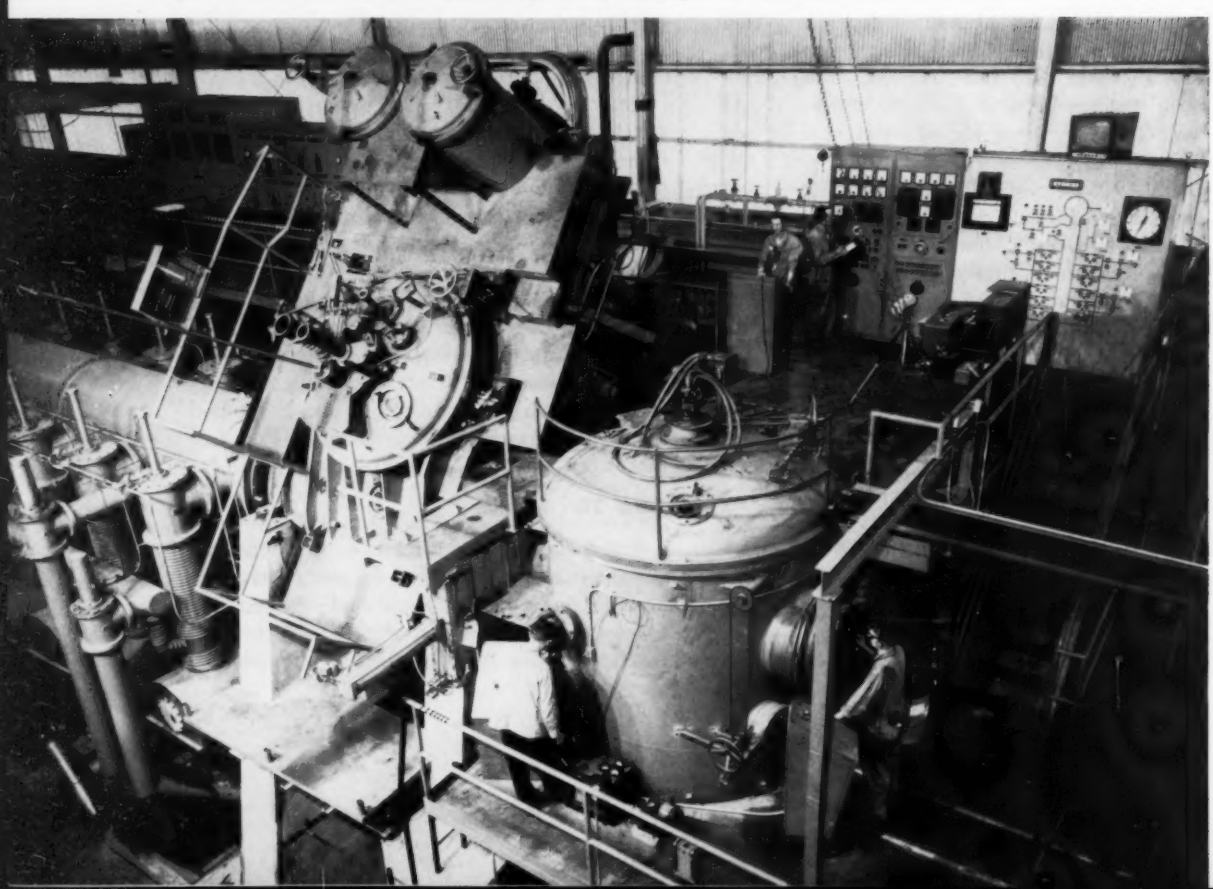


Fig. 1 – Cutaway View of 5000-Lb. Capacity Vacuum Induction Furnace. Large valves can seal off the mold chamber from the furnace chamber, or the furnace chamber from the addition units (the two vertical cylinders in the rear). Text gives the details of operation

Fig. 2 – Vacuum Furnace in Pouring Position. Furnace and twin addition cylinders tilt at the same time. Since they are integral, new heats can be prepared and melted while the preceding heat is freezing in the mold chamber



turers and users of vacuum induction furnaces. For one thing, almost unlimited sizes can be achieved in future units by merely increasing the diameter of the tilting chamber, and thereby raising the melting capacity of the furnace.

Problems connected with this furnace, particularly those occurring in the design of the large rotary seals, were considerable. Our engineers were able to solve them by intensive testing prior to making the final installation. Full-scale models were used, along with other test devices developed by Metals Div. engineers. Though economies were important, the difference in cost between our unit and a conventional furnace was only 10%.

Three generators power the furnace. Two are 550-kw., 890-cycle single-phase generators running in parallel for melting; the other is an 800-kva., 30-cycle two-phase generator for stirring. Figure 3 illustrates the wiring diagram. The 1100 kw. of melting power is supplied by the single-phase generators operating in a conventional manner. Power is fed to the furnace through busbars and flexible cables. (These permit full power to be drawn at any degree of tilt.) All connections are made outside the furnace. This high-frequency power can melt a 5000-lb. charge in about 75 min., starting with a cold crucible.

Novel Stirring System

The conventional and well-known four-loop stirring, produced by applying single-phase power, is shown in Fig. 4, left. Its big disadvantage is that any metal at the bottom of the crucible has to go through quite a tortuous path to reach the exposed surface of the bath. Because it is difficult to get the gas to the surface, a problem is created in the later stages of degassing. Also, in the mixing operation, needed in melting high-temperature alloys, it is more difficult to get good homogeneity.

Figure 4 at right shows the two-loop type of stirring produced with low-frequency multiphase (or motoric) stirring.* In this system, the metal reaches the exposed melt surface with ease, and additions are thoroughly mixed in a short time. This shortens considerably the time required for complete degasification of the melt. For example, only 60 sec. is needed to mix the aluminum and titanium additions in a 5000-lb. charge of Udimet 500.

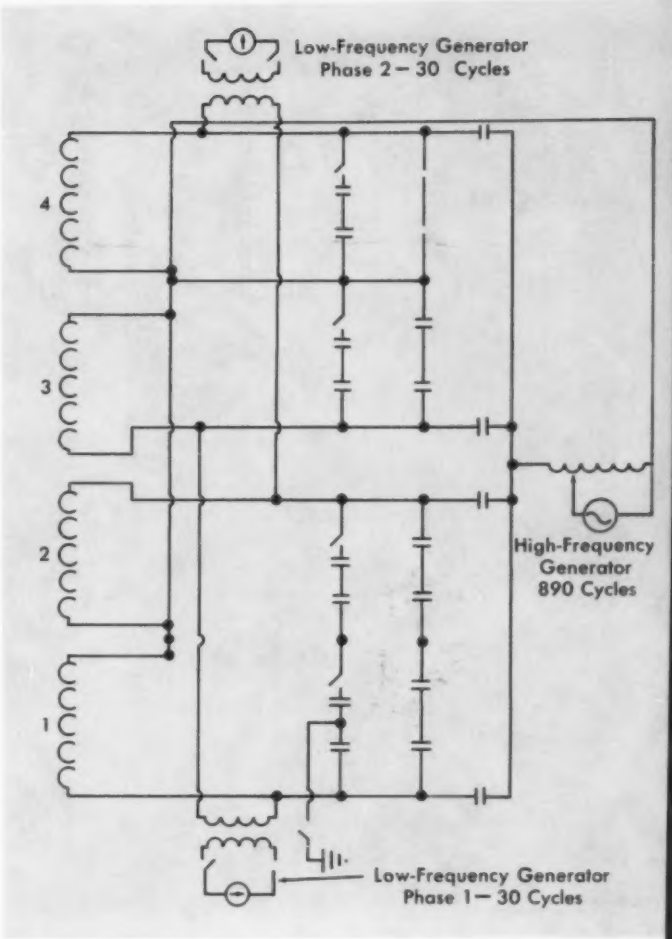


Fig. 3 – Electrical Schematic Diagram. Note that connections allow both low-frequency stirring and high-frequency melting power to be applied at the same time

Laminated Cores Used in Crucible

The use of laminated yokes marks a deviation from conventional construction. These serve two purposes: They trap the magnetic field outside the coil and provide mechanical support for the coil and crucible assembly. Identical to the cores of conventional transformers, these yokes completely surround the coil. Being very heavy and rigid, they provide excellent mechanical support for it. This helps to lengthen lining life, long a considerable cost and time problem in vacuum induction melting.

*The displacement of the phases by 90° both in time and space creates a rotating magnetic field similar to that found in a multiphase induction motor.

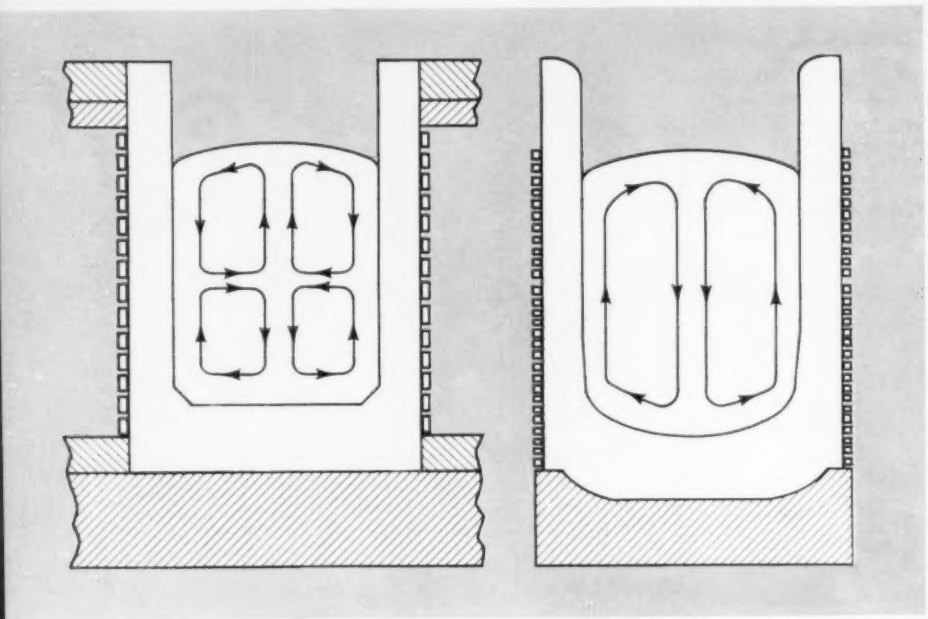


Fig. 4 – Conventional Single-Phase Stirring is Shown at Left. Note the molten metal at the bottom must go along a winding path to reach the bath surface for degassing. With multiphase stirring, this difficulty is eliminated, and homogenization of the melt is much more rapid

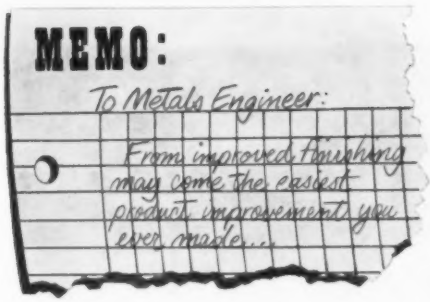
How a Heat Is Made

First, the furnace is pumped down below 20 microns to a minimum acceptable leak rate. (The leak rate method determines whether leaks have developed in the furnace since the last melt.) Power in the furnace is brought up slowly to insure that the refractory is not damaged by a sudden thermal change. The charge is molten after 75 to 85 min. A refining and degasification period follows, during which the bath is stirred. While refining, the pressure is not allowed to exceed 10 microns. When the gas level reaches a predetermined minimum point, preparations are made for making late additions. After adding them, frequency multiphase stirring is again applied, this time for 5 min. Then the control dip sample is taken and sent to the direct-reading spectrometer laboratory for chemical analysis and release. Assuming that the melt is within chemical specifications, the melt is made ready for pouring. The pour, depending on the type of mold and metal used, takes from 10 to 25 min. (Pressure at the start of pour does not exceed 5 microns.) After the pour is complete, the 30-in. valve between the mold and melt chamber is closed, separating the two chambers. The ingots are allowed to cool and freeze under full vacuum, and are not touched until the melt chamber has been prepared for the next melt.

Next, the melt chamber is opened, so the crucible can be carefully checked and cleaned. A new main charge is then added, and the cycle begins again. While this activity is under way in the melt chamber, the mold chamber is bled to atmosphere, the mold table is lowered to the floor, the filled molds are removed, new heated molds and secondary tundishes are installed. After the mold table is raised into position, the mold chamber is pumped down. When the mold chamber reaches a level of vacuum consistent with that in the melting chamber, the 30-in. valve between the chambers is opened. This operation is completed before the charge in the pot is molten.

Immediately after finishing with the mold chamber, the addition chamber is cycled. At this time, any late or any make-up additions needed to make a full charge are added to the additions maker (the two vertical cylinders), which is then cycled in a similar manner to the mold chamber.

In conclusion, this 5000-lb. furnace has increased our production capacity by approximately 500,000 lb. of alloy per month. Furthermore, its revolutionary design has proved that heats of 10,000 lb. and more can be melted by the vacuum induction process. In fact, at the present rate of industrial growth, it seems likely that construction of a 10,000-lb. vacuum melting unit will begin within the next two years.



No. 4 in a Series on Better Finishing

How to Get the Most From Solvent-Vapor Degreasing—Part I

*By T. J. KEARNEY and C. E. KIRCHER**

New equipment designed to use sprays, warm solvent baths, and ultrasonics has expanded the basic method so that an even better job can be done. This article, the first of two, describes equipment and applications. Part II next month will cover solvents and costs. (L12j)

IN RECENT YEARS, VAPOR DEGREASING has seen rapid growth as an important cleaning technique. Basically, its effectiveness stems from the physical and chemical properties of chlorinated hydrocarbons, primarily trichlorethylene and perchlorethylene. When boiled, these solvents give off dense vapors which condense on soiled parts to dissolve and flush away surface contaminants such as oil and grease and other soils.

Provides Clean Rinse

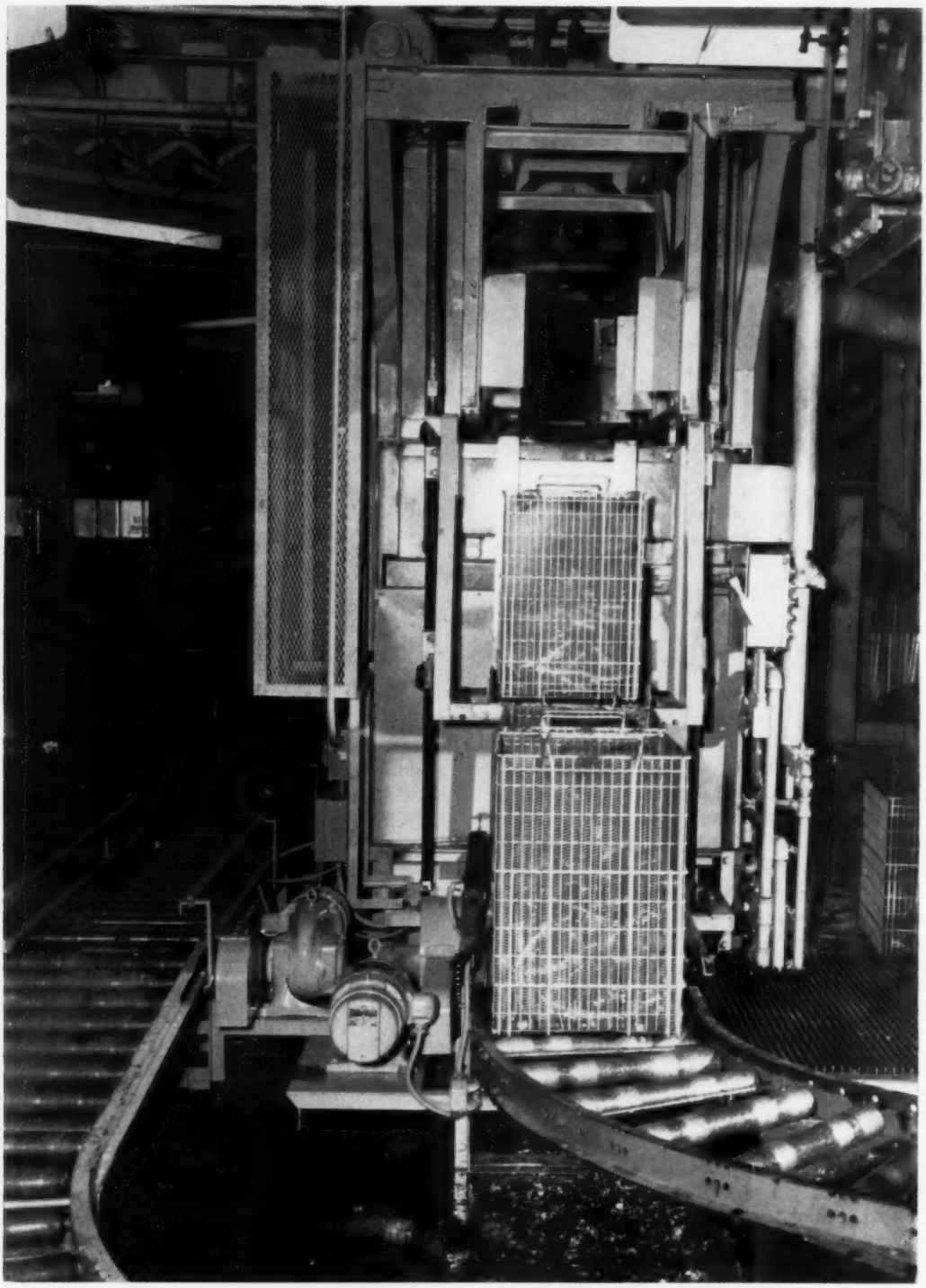
Probably the most unique feature of solvent-vapor degreasing is that it can provide a final uncontaminated rinse because the vapors contain no impurities. All soil which drips down with the distillate is not recirculated to the parts since, for the most part, a boiling solvent even though contaminated will give off only pure vapors.

Present-day equipment is not necessarily limited to cleaning with vapors alone. Instead, many units employ cleaning cycles in which parts are also immersed in hot solvents or sprayed with them. The result is more effective cleaning of metals and many nonmetallics.

A straight vapor degreaser, the simplest unit, comprises a degreaser body with a sump to hold the degreasing solvent, and a heater (usually multipass steam coils) which raises the solvent temperature to the boiling point, thus filling the cleaning zone with dense vapors. Vapor level in the unit is maintained by a narrow water jacket which encircles the machine (Fig. 1). For increased production, the jacket can be augmented by cooling coils. A sideboard or freeboard minimizes the escape of vapors out the top of the unit.

Straight vapor degreasers are usually satisfactory for removing oils and greases that are completely or nearly completely soluble in the degreasing solvent. Work to be cleaned is immersed in the vapor zone. Cleaning results from the condensation of the solvent vapors on exposed surfaces of the part. The condensed solvent dissolves the soil and carries it to the sump. Condensation continues until the metal is heated to the vapor temperature (188° F. with trichlorethylene, 250° F. with perchlorethylene). The mass of the part, thickness and specific heat of the metal determine the amount of

*Mr. Kearney is chief engineer and Dr. Kircher is manager of research, Detrex Chemical Industries, Inc., Detroit.



Flexibility of Solvent-Vapor Cleaning Is Demonstrated by This Degreaser Which Has Been Adapted to an Automated Line. Parts come down gravity roll conveyer in large baskets, are lifted into degreaser, cleaned by immersion in hot solvent and vapor rinsed

condensation required. For example, aluminum will condense twice as much vapor as the same weight of steel. To avoid recontamination, work must be definitely separated and arranged so that condensate from parts does not drain or drip over others placed below them. Temperature difference in layers of stacked parts is the limiting factor. Those on the bottom enter the vapor zone first and reach the vapor temperature sooner. Cleaning action on these parts is halted while those higher up are still cool enough to effect condensation. Soil would then be carried down through the clean parts at the bottom of the stack.

Vapor-distillate spray machines combine the features of the straight vapor unit with a spray system. Condensing capacity is greater than in a simple vapor degreaser. Work is suspended in the vapor zone for straight vapor degreasing. While still in the vapor zone, parts are sprayed with clean distillate. The spray dislodges insoluble soils from recesses and crevices and flushes away stubborn surface soils. In addition, the spray cools the work surface so that further condensation of solvent vapor – a final rinse – is possible. This overcomes, of course, the limitation inherent to straight vapor degreasing: Parts can be stacked without danger of recontamination.

As Fig. 2 shows, the extra distillate is collected in a separate sump to one side of the work zone where it cannot be contaminated by soil from the parts. Distillate flows into the solvent sump and then overflows into the boil chamber. All spraying takes place within the vapor zone to minimize vapor losses.

Vapor-distillate spray cleaning will remove soils which are partially soluble in the solvent such as polishing, buffing and honing compounds. The mechanical action of the spray helps dislodge and remove the insoluble portion. The spray also expedites removal of heavy deposits of soluble materials, assists in cleaning the interior of parts that have large cavities containing trapped air, and flushes out drilled or cored passageways in large parts.

A liquid-vapor unit requires two chambers – a boiling sump which supplies vapors and a warm solvent bath in which parts are immersed. Design is such that distillate collects in the chamber of warm solvent thereby constantly diluting it. Excess solvent overflows to the boiling sump. Figure 3 is typical of the design used when large items are to be degreased. Equipment like this is excellent for cleaning

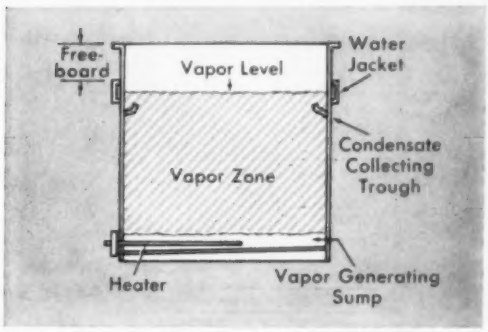


Fig. 1 – Basic Vapor Degreaser. Heater boils solvent, generally trichlorethylene or perchlorethylene, forming vapor zone. Solvent condenses on parts held in vapors, soil is dissolved, carried to sump. Water jacket sets maximum height of vapor zone; freeboard prevents vapor loss to outside air currents

tubing, drawn and extruded forms, bulk quantities of small parts covered with relatively light oils or greases, shop dirt and metallic fines.

In the cleaning cycle, parts are lowered through the vapors into the immersion chamber. Here they are washed by the comparatively clean, warm solvent and are then withdrawn slowly, often actually held a short time in the vapor zone to permit complete drainage and a vapor rinse. Solvent in the immersion chamber is maintained below boiling. Thus, when parts which have been immersed are withdrawn to the vapor zone there will be enough condensation on them to effect a vapor rinse.

Multiple immersion units (Fig. 4) incorporate a chamber of boiling solvent, a warm liquid chamber and either sufficient height above the immersion chambers to provide a vapor zone for the final rinse or a third chamber for vapor cleaning in a straight-line production sequence. Condensate is collected, for example, in the rinse chamber and overflows or is pumped to the boiling compartment. Cleaning is accomplished by immersing parts in a vigorously boiling solvent where the mechanical scrubbing action of the agitated liquid removes insolubles, heavy oils and greases. From here the work is transferred to a rinse compartment. While rinsing the parts, the warm liquid also lowers the temperature of the work sufficiently to permit a final vapor rinse.

On certain parts, particularly when metallic fines are being removed, it is often desirable to reduce the possibility of their being recontaminated. Instead of immersing the work in

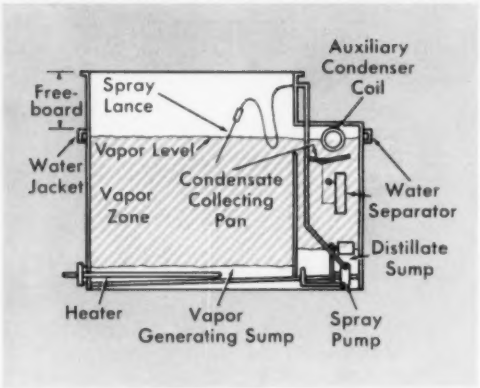


Fig. 2 – Vapor-Distillate Spray Machine. Separate sump has been added to side of basic vapor degreaser to collect uncontaminated distillate. Sprayed on parts in vapor zone, clean distillate helps loosen insoluble soils

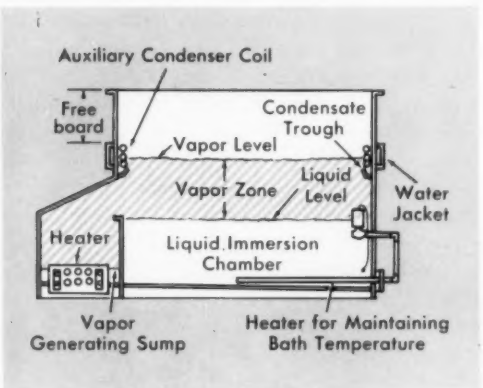
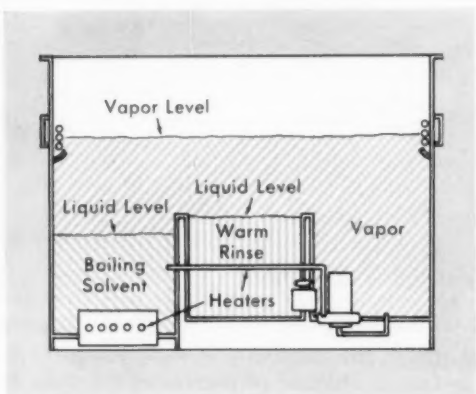


Fig. 3 – Typical Liquid-Vapor Degreaser Contains Two Chambers, One in Which Vapors are Generated, the Other to Hold a Warm Solvent Bath. When withdrawn from bath, parts are still cool enough to cause condensation for a vapor rinse



the boiling compartment, it is held in the vapor zone so that the contamination removed by the initial condensation is carried directly into the boiling chamber. The work is transferred to the warm solvent rinse chamber without immersing it in the boiling solvent and then to the vapor zone for final rinsing and drying.

Multiple immersion units provide flexible and very efficient cleaning for all kinds of work where the physical size and shape of the parts permit the use of this type of equipment. It is not likely that a large engine block, for example, would be cleaned in immersion units. Smaller engine parts, however, and others which do not have recessed or concave surfaces are cleaned quite effectively. Although more complex than other units, multiple immersion units fit well into the conveyerized production lines.

The basic vapor-spray-vapor unit (Fig. 5) consists of a boiling solvent compartment, a spray sump and vapor zone above these compartments so that the work can be completely immersed in the vapors and sprayed. The condensate is collected in the spray sump to dilute and clarify it. Overflow is fed into the boiling chamber.

A second boiling compartment or "concentrator" can be added if considerable quantities of oil are encountered. For removing firmly adhering soils, a second spray sump and battery of spray nozzles are often installed. On highly buffed brass and aluminum which is to be lacquered, a final distillate rinse sprayed over the work is desirable. Filters, strainers, or both, should be included in the spraying system depending upon the type and quantity of soil being removed.

In the vapor-spray-vapor cycle, work is passed through the vapors and carried quickly into the spray zone before the soluble portion of the gross soil, such as the carrier in a lapping compound, is completely removed. The warm solvent spray then dislodges and washes away the heavy soil, even though part of it may be insoluble, and leaves the parts cool enough for a final vapor rinse.

Besides removing polishing, buffing, lapping, and drawing compounds, vapor-spray-vapor

Fig. 4 – Multiple Immersion Unit Incorporates a Chamber of Boiling Solvent, a Warm Rinse Chamber and a Vapor Zone. Boiling action loosens heavy, insoluble soil; warm liquid rinses and cools parts so that vapor rinse will be effective

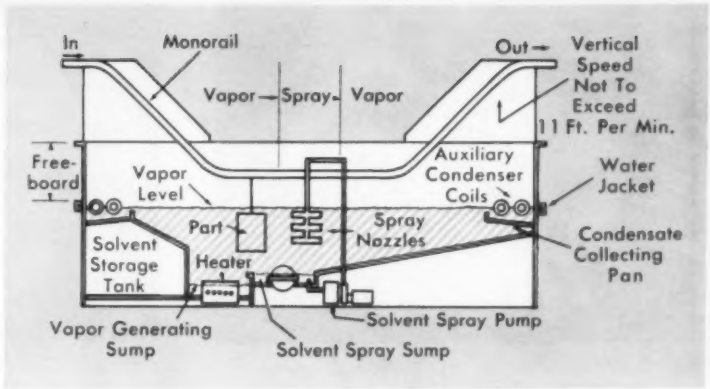


Fig. 5 — Vapor - Spray - Vapor Degreasing Unit Is Adaptable to All Types of Overhead Conveyer Systems. Parts enter vapor zone, pass through spray area, then through vapor rinse zone

degreasing is also used where large cavities, blind holes and partially shielded areas must be cleaned. The solvent spray breaks the air pockets and washes the interior of the part.

Ultrasonic degreasing combines a precleaning cycle, normally one employed for removing stubborn adherent soils, such as vapor-spray-vapor or immersion cleaning, with a subsequent treatment by immersion in a liquid bath of the degreasing solvent which is ultrasonically agitated (Fig. 6). The solvent temperature is accurately controlled in a range where maximum agitation can be produced. Transducers placed in the bath either at the bottom or on the sides supply the power necessary for agitation. Efficient filtration must be provided down to the 2, 5 and 10-micron level, depending upon the class of the work and the type of soil being removed.

After parts have been carried through the precleaning cycle and immersed in the ultrasonically agitated bath, they are usually sprayed with uncontaminated distillate, rinsed in vapor and then dried. Equipment is designed so that the spray falls into the sonics chamber, which in turn overflows to the rinse chamber of the precleaning cycle, then to the boiling sump.

Sufficient heating and condensing ability must be incorporated in the unit to provide a high distillation rate so that adequate solvent will be available for the distillate spray. For this purpose auxiliary distillation equipment is almost always included in ultrasonic cleaning units.

The highest degree of cleanliness is desired when ultrasonic degreasing equipment is employed. It is capable of producing cleaning results not obtainable on any production basis. However, constant attention and proper maintenance are imperative to insure that equipment

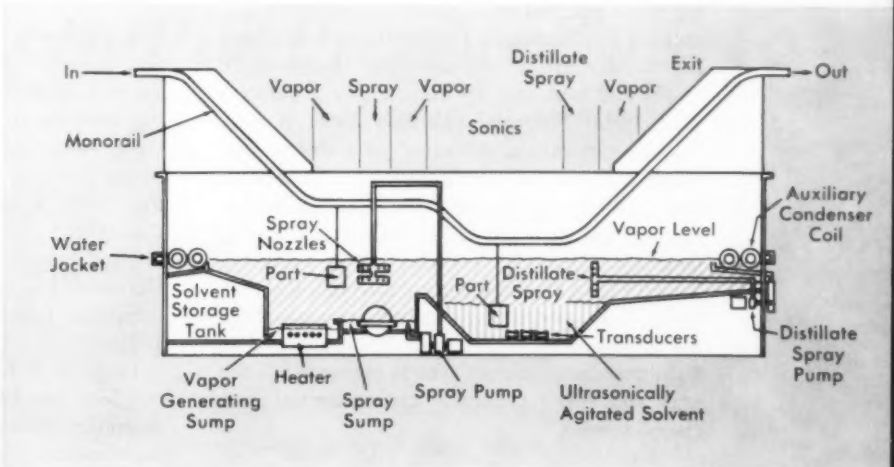


Fig. 6 — Employed in the Most Exacting Cleaning Jobs, Ultrasonic Degreasing Equipment Also Includes One of the More Conventional Solvent-Vapor Degreasing Cycles, Such as the Vapor - Spray - Vapor System Shown Here, for Precleaning the Work. Coming out of the ultrasonically agitated bath, parts are sprayed with clean distillate, and vapor rinsed

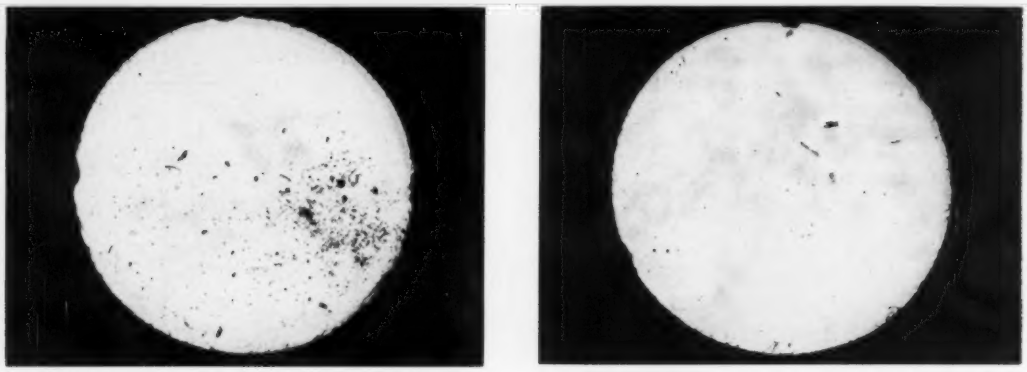


Fig. 7 – Comparison of Residual Soil on Roller Bearing Cones After Washing, Rinsing, and Flushing in Oil (Left) and After Ultrasonic Degreasing (Right). Average soil weight on oil-washed cone was 0.0188 g.; on ultrasonically degreased cones, 0.0004 g.

is operating at maximum efficiency at all times. Since the degree of cleanliness desired is so critical, it must be checked often by determining residual soil on quality control samples.

An example of the superior results that can be obtained by ultrasonic degreasing is illustrated in Fig. 7 which compares residual soil on roller bearing cones after washing and ultrasonic cleaning. One part was washed in oil, rinsed, then flushed in filtered oil. The other was cleaned in an ultrasonic degreasing cycle consisting of vapor-spray-vapor precleaning, and immersion in an ultrasonically agitated bath of filtered trichlorethylene at 140° F. with the immersed transducers operating at a frequency of 400 kc. The average power intensity at the transducer was 16 watts per sq.in. Parts were subjected to watt densities many times this intensity as they passed through the focal zone of the shaped transducer.

More Special Applications

The unique characteristics of vapor degreasing have resulted in a growing number of specialized applications. One of these is in cleaning the interior of fuel tanks for missiles, tank trucks and tank cars by using vapor generators (see *Metal Progress*, February 1960, p. 88). Solvent vapors are generated in a closed container and conducted through pipe or flexible hose to the vessel to be cleaned. Condensation of the vapors on the metal surface thoroughly degreases the interior of the vessel. Cleaning is continuous since heat is lost through the tank wall, thus permitting further condensation. All soluble soil is removed without residue. Substantially all the solvent is recovered if the tank and vapor generator are connected in a closed system.

Solvent-vapor degreasing also lends itself well to cleaning precision controls which have complicated cored or drilled bodies, tubing and flexible hoses, and other parts whose dependability is almost directly proportional to their cleanliness. For example, ultrasonic degreasing has proved to be the most satisfactory method for cleaning components of hydraulic, pneumatic and liquid fuel control systems. In a specific application, ultrasonic degreasing reduces the carbon content on an electronic tube part from 0.01% (considered clean by former standards) to 0.002%. In another installation, the ability of ultrasonic degreasing to remove loose carbon from the carbonized anode for a gas-filled thyraton improves the surface cleanliness enough to permit this type of tube to operate under more stringent conditions.

New Finishing Technique

A promising development in metal finishing incorporates solvent degreasing and flow coating in a single unit. Since cleaning and painting are done in one unit, floor space and operating costs are reduced. Contamination between cleaning and painting is prevented since the work is maintained in the vapor zone throughout the process. The elimination of fire and explosion risk by using a nonflammable chlorinated hydrocarbon solvent allows almost complete freedom in locating the finishing system.

Progress in formulating resins with trichlorethylene has been rapid and paints of many desirable characteristics should be available for application by this system.

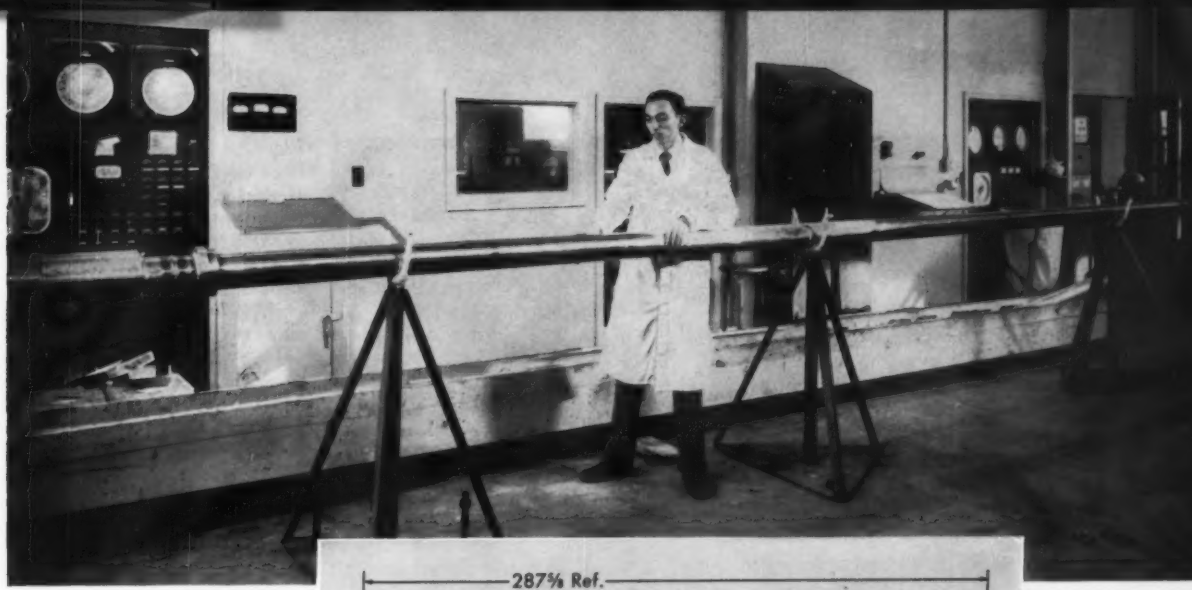


Fig. 1 — Used in Pressurized-Water Reactor, This Zircaloy-2 Pressure Vessel Serves as a Container for Fuel Elements on Which Radiation Tests Are Being Made. Components, machined from extrusions and forgings, were welded together to form the complete assembly

Progress in Reactor Technology

Fabrication of a Zircaloy-2 In-Pile Pressure Tube

*By J. G. GOODWIN**

Successful fabrication of Zircaloy-2 into a critical reactor component demonstrates that with special attention it can be formed into shapes by conventional methods despite its undesirable working characteristics. (F24, K1d, G17, T11; Zr-b)

THE EFFECT OF IRRADIATION on fuel element assemblies has been studied by inserting specimens in a stainless steel pressure tube in the center of a test reactor. Some tests being conducted require higher heat outputs than can be generated solely by the fissioning of natural uranium (U^{238}). Greater neutron flux and a resultant increase in heat output are pos-

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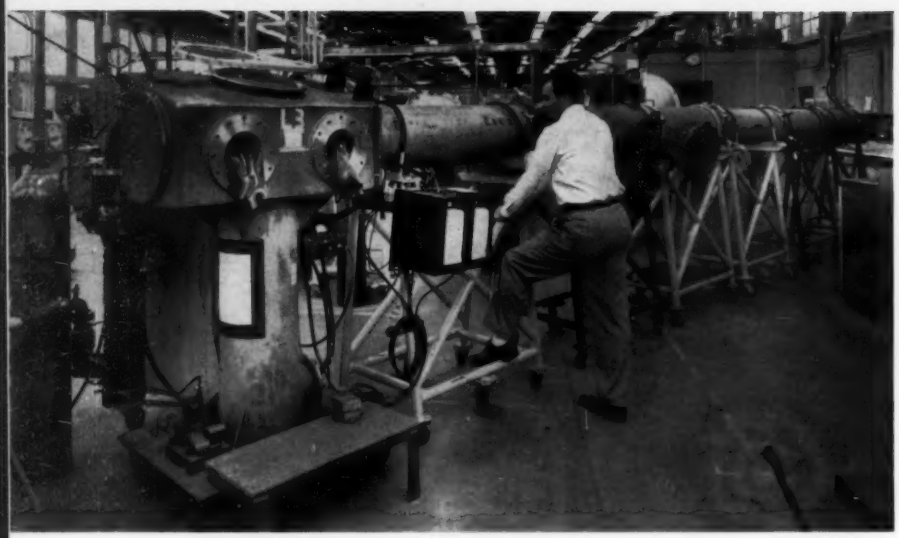


Fig. 2 – Special Chamber in Which Upper Head, End Cap, and Supporting Ring Were Welded to Pressure Tube. Chamber was evacuated to 0.03 micron, then filled with helium at a pressure of 1 atm. for welding the Zircaloy-2 parts

sible if the fuel is enriched with U^{235}. This, however, is not the complete answer to greater heat generation. Although U^{235} increases fissioning, it does so at an ever decreasing rate because of its high neutron absorption. This cuts down the percentage of neutrons available for fissioning and limits the effective quantity of U^{235} which can be added to the fuel. The only other way to increase neutron flux is to make the pressure tube from a metal such as Zircaloy-2 which absorbs fewer thermal neutrons than stainless steel.

Zirconium Alloy Chosen

This requirement is met by Zircaloy-2 which not only has low thermal-neutron cross section (0.2 barn compared with about 2.5 to 3.0 barns for stainless steel), but also excellent corrosion resistance and adequate strength under the operating conditions in the pressurized-water reactor.

The vessel, shown in Fig. 1, is 4.520 in. O.D. by 3.136 in. I.D. by 22 ft., $\frac{3}{8}$ in. long. Had a 1500-lb. ingot been available, it could have been forged and bored to make the tube but ingots on hand were limited to 1000 lb. Also, scrap losses in this method of fabrication would exceed 50% of the original ingot weight.

Extrusion remained the only practical method for making the tube. It offered the possibility of either joining several extruded sections by welding to obtain the required length or by extruding the entire length of the tube at one time. The former technique was ruled out because of the limited knowledge of the behavior of Zircaloy weldments in a neutron flux. The alternative method – that of extruding the tube as one continuous length – was chosen although similar experience was limited to short jacketed extrusions for the production of small-diameter tubing for the Shippingport reactor. Ingots as heavy as 1000 lb. had not been extruded directly into tube. For this reason, it was decided to investigate the proposed fabricating technique by first making a similar tube from a 600-lb. nonreactor-grade ingot. With but minor changes, the technique used to make the development tube proved satisfactory.

Heavy Billet Extruded

The first step in the production of the pressure vessel was to heat a 968-lb. Zircaloy-2 ingot to 1800° F. in a $BaCl_2$-NaCl salt bath. After being upset in an extrusion press, it was machined to a diameter of $12\frac{1}{8}$ in. Then a $3\frac{1}{8}$-in. hole was bored through its center.

Alignment of the press was checked by extruding several S.A.E. 1050 billets at 2200° F. The Zircaloy billet, heated in the salt bath to 1800° F., was then extruded using a mandrel faced with Stellite and a split, hot work tool-steel die. Mandrel, die and container liner were lubricated with a mixture of 5 parts Led Plate, 1 part MoS_2 and enough Ucon oil to make a paste, and a proprietary preparation.

To keep it as straight as possible, the tube was caught in a steel run-out guide. No laps, folds or pits were detected and the front of the extrusion was not excessively eccentric.

Machining was done by the Naval Gun Fac-

tory, Washington, D. C. Inspection here revealed that the tube had a maximum bow of 3.0 in., a maximum I.D. of 2.903 in., and a minimum O.D. of 4.750 in. The bow, probably caused by a similar deviation in the run-out guide, was removed by cold straightening with a hydraulic press. Approximately 100 deflection cycles were required to bring the tube to within 0.120 in. of exact straightness. (Maximum deflection was 7½ in.)

Next the I.D. was bored to 3.00 in., then machined to the final diameter of 3.132 in. Since the front end of the extrusion contained the maximum eccentricity, it was machined first when making the finish cut. This practice reduced the deviation from straightness. With its I.D. completed, the tube was again straightened and samples for chemical analysis were machined at 2-ft. intervals along its length. The O.D. was then finished to 4.525 in. Eccentricity of the bore and O.D. was found to be 0.0065 in. Radiographic, fluorescent dye penetrant, and ultrasonic tests revealed no defects.

As shown in Fig. 1, the pressure vessel assembly is made up of an upper head or transition piece, support ring, and end cap which are welded to the tube. The upper head, forged and machined from Zircaloy-2, serves as a transition joint from the pressure tube to the stainless steel piping above the reactor. The support ring was also machined from forged Zircaloy-2. It supports the pressure tube in the reactor. The end cap, a machined extrusion, seals the bottom of the pressure tube.

Welds Made in Special Chamber

One of the most critical steps in the fabrication of the pressure vessel was welding the components to the tube. Experience in making the development vessel demonstrated that best results were obtained when welding was done in a chamber filled with inert gas. Shielding was not satisfactory. For circumferential welds, a joint with a 0.100-in. root thickness with a 15° taper from radius to O.D. proved to be satisfactory.

Each of the Zircaloy-2 components, with the exception of the tube, was degreased in acetone, dried in alcohol and pickled in a water solution containing 35% HNO_3 and 5% HF. It was decided that the upper head should be the first component welded to the tube so that the I.D. of the weld could be examined after the root pass to ascertain if penetration was complete. The upper head and tube were aligned and tack welded together in an argon shield. Welding was performed in the 30-ft. chamber shown in Fig. 2 which was sealed, evacuated for 12 hr. to 0.03 micron, filled with helium of 99.99% purity at a pressure of one atmosphere. Welds were made with a straight-polarity, thoriated-tungsten electrode. The chamber is also equipped with a mechanical rotating device which revolved the tube at ⅔ rpm. during welding.

The tungsten electrode and Zircaloy-2 filler metal are potential sources of base-metal contamination. Tungsten contamination can be

Fig. 3 – Upper Head and Support Ring of Pressure Vessel. Head, welded to top of the pressure tube, was machined from a forging. Ring supports vessel in the reactor during radiation tests. Welds were made in special chamber (Fig. 2)

Fig. 4 – End Cap, Welded to Bottom of Pressure Tube, Was Machined From an Extrusion

Table I – Tensile Properties of Zircaloy-2 Pressure Vessel Components

	Yield Strength		Tensile Strength		Total Elongation		Reduction in Area	
	Room Temp.	650° F.	Room Temp.	650° F.	Room Temp.	650° F.	Room Temp.	650° F.
Tube:								
Longitudinal (*a*)	52,100 psi.	20,100 psi.	77,100 psi.	33,000 psi.	16%	19%	29%	29%
Transverse (*b*)	74,000	32,000	81,300	36,600	24	43	30	57
End cap:								
Chord (*b*)	56,000	25,500	65,500	30,900	8	38	7	56
Transverse (*b*)	—	21,500	—	28,400	—	19	—	16
Longitudinal (*a*)	61,800	22,100	73,100	29,500	—	20	33	61
Upper head and support ring:								
Transverse (*b*)	72,100	31,400	78,000	34,700	22	38	27	52

(*a*) 2.0-in. gage length. (*b*) 0.5-in. gage length.

minimized by preventing the electrode from touching the molten Zircaloy pool; contamination of the base metal with carbonaceous materials and oxygen and nitrogen from the filler rod is avoided by removing all laps and seams, and degreasing, pickling and rinsing the rods.

Examination of the metal deposited during the root pass revealed complete penetration of the weld and no evidence of porosity. Five layers of filler metal were subsequently required to complete the joint.

Both the end cap and support ring were welded to the tube in the protective atmosphere of the welding chamber. Figures 3 and 4 show closeups of the external surfaces of the three welds. Other weldments included five groups of three beads which were deposited on the outside surface of the tube. Spaced 120° apart on the tube circumference at 4-ft. intervals along its length, the beads provide uniform clearance between the Zircaloy tube and an aluminum tube into which it is inserted in the reactor.

Maximum deviation of the vessel from true straightness proved to be 0.040 in. – essentially the same as that before welding. Additional straightening was not necessary.

Only two small voids were detected during examination of the welds. These were not cause for rejection. Eccentricity between the upper head and tube was 0.030 in. but the misalignment was corrected on the O.D. by taking a machining cut to insure that acme threads, support ring, and tube would be concentric.

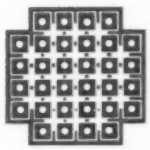
Final machining consisted of removing excess weld metal on the I.D. of the upper weld (to prevent binding during installation and removal of test assemblies) and cutting the acme threads on the O.D. of the upper head. The seat for the O-ring seal on the I.D. of the upper head was also cut, then finished to 32 rms. with a bearing scraper.

Corrosion characteristics of the completed vessel were checked by exposing the I.D. to water at 650° F. and 2500 psi. for seven days. With two exceptions, the corrosion film was black and lustrous throughout the tube. A thin, superficial white film covered areas at the upper weld and beneath the support ring. It probably formed at the upper weld because the tube was not pickled before being joined with the head. Beneath the support ring, the white corrosion product most likely stems from incomplete air removal in the welding chamber.

Additional corrosion tests were carried out on coupons taken from each component during fabrication. These were exposed to steam at 750° F. for 14 days. All samples had acceptable corrosion resistance.

Mechanical tests were also performed on other coupons. No standards for mechanical properties of extrusions and forgings are available, but the test results, some of which are shown in Table I, revealed no serious metal weakness or lack of ductility.

In addition, a 36-in. section of the development tube, made of nonreactor-grade Zircaloy-2 to establish best fabrication techniques for the pressure vessel, was tested hydrostatically. It ruptured at 650° F. when pressurized to 9900 psi. in a shear-type fracture with considerable yielding before failure. Based on stress calculations and the ductile failure in the burst test, it was concluded that the pressure vessel would perform satisfactorily at the maximum pressure of 2500 psi. at 650° F. Its successful operation in the test reactor for more than two years bears this out.



Progress in Reactor Technology

Recycling Zircaloy Scrap

By B. F. RUBIN
*and R. F. GESSNER**

Large quantities of Zircaloy are used for cladding fuel elements and as structural components in nuclear reactors. To conserve material and to reduce costs, solid scrap and ingot conditioning chips can be treated and remelted. (A11d, B13; Zr-b, RM-p)

ZIRCONIUM ALLOYS HAVE FOUND wide application in water cooled and moderated reactors because of their excellent nuclear and mechanical properties and corrosion resistance. These properties must measure up to strict requirements established by the Government in its specification, MIL-Z-19859A, "Zircaloy-2 Wrought Products". The specification lists mechanical properties and corrosion standards which must be met. Also, 21 impurity elements must be held within definite limits; ten of these are restricted to less than 0.005% (50 ppm.).

In processing zirconium sponge for reactor components, large quantities of scrap metal are generated. Only 20% of the Zircaloy-2 ingot weight allocated to a nuclear core ends up in finished components. The remaining metal is lost as various forms of scrap. Each processing or fabrication step – ingot melting and conditioning, ingot conversion to strip or shapes, machining of components and component assembly – contributes to this 80% material loss.

Zirconium sponge ranges in price from $5.00 to nearly $8.00 per lb. Substantial savings in reactor material costs can thus be achieved by

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devising economical processing methods that permit maximum amounts of scrap to replace costly sponge in the fabrication of components.

To meet the exacting requirements of MIL-Z-19859A, zirconium scrap processing must insure that tramp metals are not introduced into the ingot, that the various zirconium alloys are segregated, and that the material is free of oxide coatings from previous fabrication. Scrap in the form of highly pyrophoric machine chips and turnings must be handled in small quantities because of fire and explosion hazards. Finally, scrap processing costs must be sufficiently low to create an economic incentive.

In recent years, methods of economic recycling have been developed for several forms of Zircaloy scrap such as the ingot turnings, crowns and solid conversion trim (tailings and edge shearings from strip) shown in Fig. 1. Quantities of scrap up to 25% of ingot weight have been added to sponge to make several hundred production ingots meeting all specifications for reactor use. While large amounts of solid scrap have been added to sponge, the compacted electrodes sometimes lack sufficient green strength for handling and melting.

Since scrap is generated at several stages during fabrication from ingot to reactor component, it varies in chemistry, shape, density, and pyrophoricity. These characteristics can be examined by a review of the various fabrication steps.

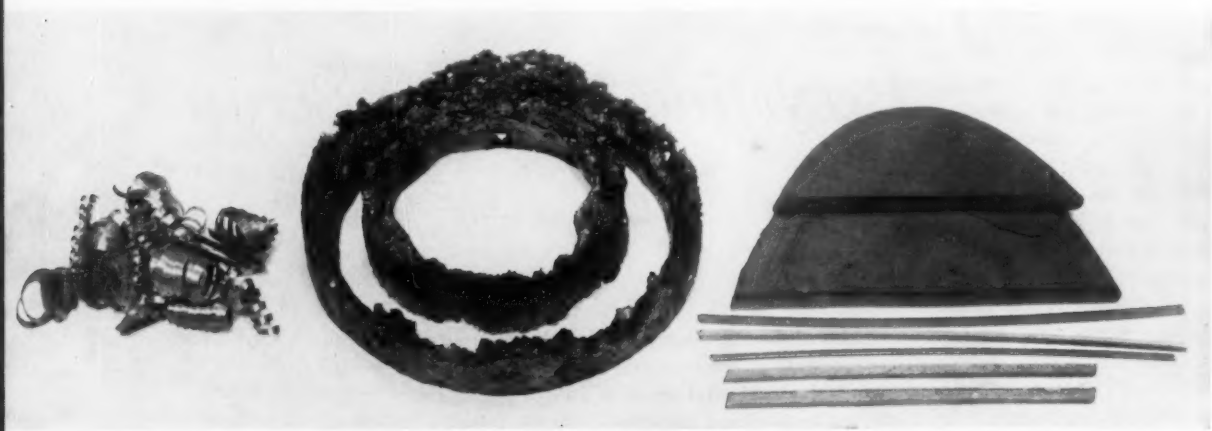

Fig. 1 — Typical Zircaloy Scrap. Left to right: ingot conditioning turnings, ingot crowns, and tailings and edge shearings. Much of this scrap can be recycled after being processed

Sources of Scrap

Zirconium sponge, with the powdered alloying elements of tin, iron, nickel and chromium, is pressed into compacts or bars which are usually welded together to form a large electrode. The electrode is double-vacuum-arc melted in a water cooled copper crucible. Typical ingots are 16 in. in diameter and weigh 2000 to 2500 lb. A thin crown or spatter ring at the top of the ingot is removed and the ingot is then conditioned to eliminate subsurface porosity. This is usually accomplished by lathe turning to a depth of about ¼ in. No cutting fluid is used. The ductile ingot turnings are about 0.032 in. thick.

The conditioned ingot is usually forged or bloomed, surface conditioned, and then hot rolled to strip of the desired thickness. The strip is sheared or cut to dimensions for machining the desired components. Tails and edges are trimmed from the hot rolled strip and this scrap, about 3/16 to ¾ in. thick, is termed conversion trim.

Hot rolled strip may be machined to final dimensions for reactor structural units, or machined to a component which may undergo further fabrication, such as in-fuel element manufacture. Machining operations are often extensive and may result in nearly 50% of the hot rolled weight of the strip being removed as chips and turnings. These turnings are thin

(0.003 to 0.010 in.) and are coated with a water-soluble cutting fluid. Despite the coolant, the friction from the high machining feeds and speeds raises the oxygen content of the chips to about 1½ times that of the solid stock.

Table I gives types and characteristics of scrap generated while making reactor components. Figure 2 shows scrap after processing.

Scrap Properties

Ingot conditioning scrap (lathe turnings and crown) amounts to about 5% of the ingot weight and is processed only after the ingot itself has met specification requirements. Chips are crushed in a hammer mill crusher, conveyed over strong magnets to remove magnetic contaminants, and then sized on a 20-mesh screen to eliminate fine particles. To minimize the fire hazard, chips are crushed in small batches and are stored some distance away from the crusher.

Chips machined from the ingot surface are susceptible to copper contamination because the ingot solidifies within a copper crucible. They may also be contaminated with nitrogen and oxygen should the furnace leak. Consequently, processed chips are analyzed for impurities; the satisfactory lots of chips are then compacted with the sponge for melting or placed in the bottom of the crucible for starting the electric arc.

Ingot crowns that are cut from the ingot tops as part of the conditioning treatment are crushed into small segments and then pickled in an aqueous solution containing 35 vol.% nitric acid and 5 vol.% hydrofluoric acid. Like the processed chips, these can be added to the sponge compact or to the bottom of the crucible for starting the electric arc.

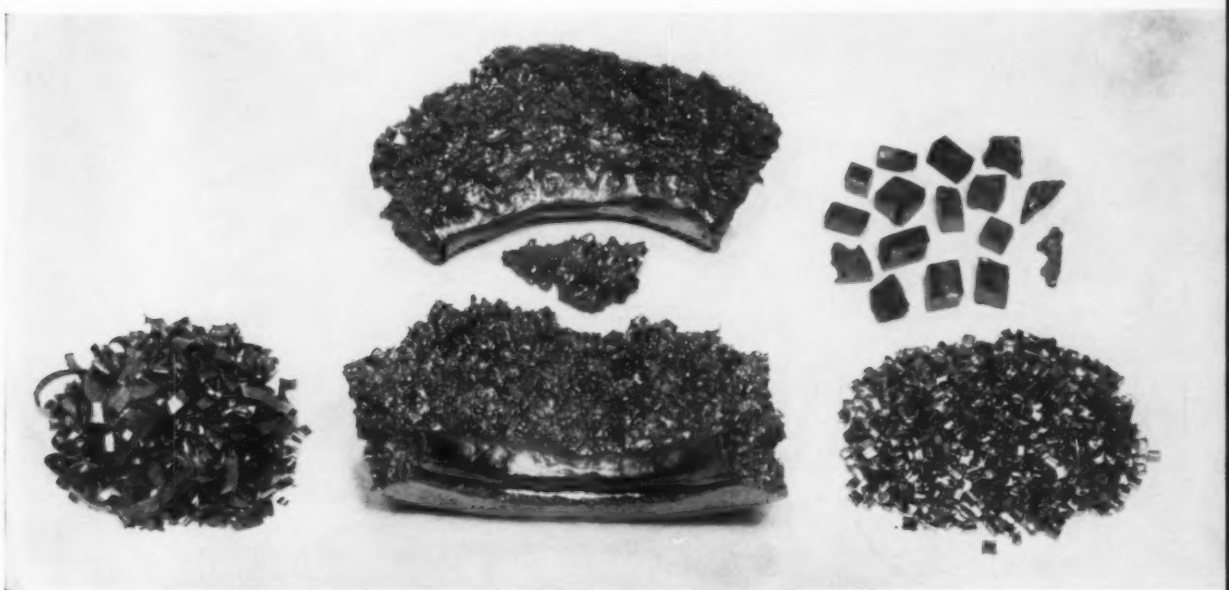

Fig. 2 — Processed Zircaloy Scrap. Crushed ingot turnings (left), pieces of ingot crown (center), and pellets chopped from strip shearings and tailings (right) can be compacted with zirconium sponge to make consumable electrodes

Most conversion trim (tails, shearings, edge trim) measures 0.200 to 0.750 in. thick. This is chopped into pellets for compacting with the sponge. After sorting, scrap is grit-blasted, chopped to size, degreased and etched (although not necessarily in this sequence) to provide clean Zircaloy cubes up to about ½ in. on a side.

Purity Important

Since the processed scrap must have a chemical purity equivalent to that required by the military specification, it must be checked thor-

oughly to insure that impure lots are eliminated. Positive identification of each piece or batch of trim is important to establish the origin of the zirconium alloy being processed. A beta-gamma counter is passed over the scrap to detect uranium or other radioactive material that may have been accidentally mixed in with Zircaloy. Magnetic, sparking, and chemical spot tests isolate and remove other extraneous materials. Small amounts of steel, copper, titanium, aluminum, hafnium, uranium, and boron, that had been accidentally mixed with the Zircaloy during handling or storage, have been found and removed during the processing of about 150,000 lb. of Zircaloy scrap.

Steel shot is used to blast surface oxide from the scrap. Use of aluminum oxide for this purpose has been discontinued because some of the abrasive particles embed in the Zircaloy, thus increasing its impurity content. Care must be taken in blasting the edges of the scrap pieces since surface irregularities and laps make the oxide difficult to remove.

Conversion trim may be chopped into pellets with alligator or edge shears. The pellets are degreased with conventional equipment and then etched in the nitric-hydrofluoric acid solution. Since the texture and sheen of etched Zircaloy are distinctive, they permit, upon visual examination of the pellets, further identification of non-Zircaloy material. A final check of scrap purity is made by taking a representative sample weighing 2% of the lot weight with a Jones Riffle or similar device and melting this into an evaluation ingot. This ingot is then sampled and chemically analyzed.

Trim scrap that is thicker than ¾ in. can be forged or rolled to ¼ to ½-in. thickness, and then processed as described. Zircaloy is forged between 1700 and 1800° F.; rolling is done at 1550 to 1650° F. Scrap that is thinner than 0.200 in. may be chopped into small 3/16-in. cubes for alloying with enriched uranium fuel, and processed in a similar manner to that of the thicker material.

As an alternative, the chopping step can be eliminated and the sections of blasted scrap may be tack welded, after degreasing and etching, into an electrode which is then melted into a 100% scrap ingot by consumable arc melting. This method has been followed in casting some reactor structural parts.

Table I – Characteristics of Zircaloy Scrap Generated in Converting an Ingot to a Reactor Component

Form of Material	Processing Step	Type of Scrap Formed
Cast ingot	Lathe turning to give a surface-conditioned ingot	Large, dry chips and turnings, about 0.032 in. thick; ingot crowns
Conditioned ingot	Blooming and hot rolling to produce strip	Tailings and edge trim, 0.200 to 0.750 in. thick
Hot rolled strip	Machining to dimensions for components	Thin, wet chips and turnings 0.010 in. thick
Assembled components	Etching	Zirconyl fluoronitride in pickling solution

Machine Scrap Lost

No economical process has yet been developed that satisfactorily prepares machine scrap for melting. Serious obstacles that prevent direct recycling are the difficulty of keeping the chips free of metallic impurities, and of removing tramp metal. The thickness of the chips (0.003 to 0.012 in.) creates problems in crushing. Chips of this size are dangerously pyrophoric and create problems in handling and storage.

An electrolytic method for refining machine scrap to a high-purity powder is being developed. It may overcome processing difficulties. Another proposal involves burning the machine scrap to ZrO_2. Since ZrO_2 is an intermediate compound formed during the production of zirconium sponge, it can, in the form of burned chips, be introduced into the sponge process.

The Zircaloy dissolved in nitric-hydrofluoric acid pickling solutions during component fabrication is also considered nonrecoverable. Some studies have shown that there is about one pound of Zircaloy in the form of a complex fluoronitride per 5 gal. of solution – too low, at this time, for economic recovery.

Record breaking Atlas missile billows flame and vapor as she launches 4¼-ton satellite into orbit. Constructed of Type 301 Nickel Stainless Steel, Atlas is built by Convair (Astronautics) Division of General Dynamics Corporation. *U.S. Air Force photo*

130 tons of missile with a skin thinner than a window pane!

The Nickel Stainless Steel skin of the Atlas missile is actually about one-third as thick as the glass in your window.

And yet look what this skin does:

- It is the sole structural framework for Atlas—130 tons of dead weight at the moment of firing.
- It serves as the wall of the propel-'ant tanks in Atlas' weight-saving design.
- It withstands the deep chill of liquid oxygen (−297°F) . . . the high heat of supersonic speed (400°F–600°F).

. . . And it is less than 1/25 of an inch thick!

No wonder they call stainless the space age metal. No wonder engineers turn more and more to Nickel Stainless Steel as temperatures rise . . . as speeds soar . . . as demands get more and more severe.

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The International Nickel Company, Inc.
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INCO NICKEL

NICKEL MAKES STEEL PERFORM BETTER LONGER

Circle 1317 on Page 48-A

Mechanical Properties of Zircaloy-2

(Numbers in Parentheses Refer to Sources of Information Listed at Right, Center)

Tensile Properties

Condition	Test Temperature and Direction*	Yield Strength (0.2% Offset)	Tensile Strength	Elongation		Reduction of Area	Hardness (DPH)
				Uniform	Total		
Vacuum Melted Zircaloy-2 Sheet, Hot Rolled and Base Annealed (3)							
As received (*a*)	Room (L)	45,000 psi.	72,000 psi.	15%	27%	44%	—
	Room (T)	62,300	69,300	9	31	52	—
	500° F. (L)	19,100	37,900	17	39	62	—
	500° F. (T)	25,900	34,500	22	48	72	—
	700° F. (L)	15,400	31,900	18	37	60	—
	700° F. (T)	20,300	29,400	16	44	78	—
Base anneal (*b*)	Room (L)	43,500	71,000	15	26	40	—
	Room (T)	61,100	66,900	11	32	53	—
	500° F. (L)	18,000	36,200	18	41	63	—
	500° F. (T)	24,000	31,900	22	52	76	—
	700° F. (L)	13,700	26,600	21	40	66	—
	700° F. (T)	17,300	26,500	19	48	78	—
Effect of Cold Work (4)							
Cold reduced 0%	Room (L)	66,200	82,600	—	—	—	210
10%	Room (L)	81,100	92,200	—	—	—	228
25%	Room (L)	90,600	103,800	—	—	—	231
40%	Room (L)	96,500	107,000	—	—	—	243
60%	Room (L)	97,100	111,200	—	—	—	256
As-Welded Properties							
Welded and annealed	Room	59,600	78,400	—	18.9	—	—
	600° F.	24,800	36,000	—	28.6	—	—
Heat Treated in the Alpha-Plus-Beta Phase Region (4)							
As received (*a*)	Room (L)	45,200	67,900	—	27.8	38.1	—
1550° F. (*c*)	Room (L)	44,600	66,400	—	26.0	31.0	—
1650° F. (*c*)	Room (L)	45,300	66,900	—	24.6	29.9	—
1750° F. (*c*)	Room (L)	44,100	63,500	—	18.1	22.2	—

*L is longitudinal, T is transverse; both samples from strip.
(*a*) Hot rolled 1550° F., annealed 15 min. at 1550° F., air cooled.
(*b*) 20 hr. in vacuum at 1375° F., furnace cooled.
(*c*) 8 hr. at temperature, furnace cooled.

Creep Properties

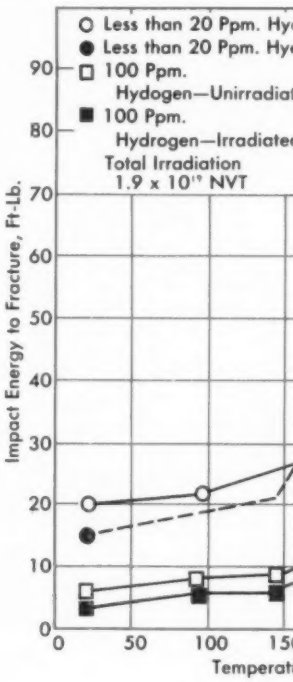
Condition	Test Temp.	Stress, psi.	Plastic Strain on Loading	Strain Intercept (ϵ_o)	Creep Rate In./In./Hr.	Transition Point		Rupture	
						Elong.	Time	Elong.	Time
Base anneal	250° C.	32,000	4.67%	—	5×10^{-2}	—	—	26.6%	2.5 hr.
Base anneal	250	30,000	2.35	11%	2×10^{-6}*	11.2+%	990+hr.	—	†
Base anneal	250	28,000	1.53	4.0	2×10^{-6}*	4.6+	1740+	—	†
Base anneal	250	26,000	1.859	2.55	1×10^{-7}	2.5+	800+	—	‡
Base anneal	350	27,000	5.0	12.4	6.2×10^{-4}	18.4	87	21.55	88
Base anneal	350	25,000	3.39	6.7	2.3×10^{-5}	15.47+	3794+	—	†
Base anneal	350	23,000	2.09	—	§	2.62+	162+	—	‡
Beta quenched	250	57,500	0.25	0.65	1.6×10^{-4}	2.8	68	4.9	69
10% cold work	250	56,000	0.19	0.25	3.5×10^{-6}	0.76+	475+	—	*
10% cold work	350	51,000	0.06	0.71	1.9×10^{-4}	3.0	173	7.86	287
Base anneal 10% cold work	250	46,000	0.08	0.48	1.15×10^{-2}	1.9	12	6.18	14

*Test was run in spring machines (estimate only).
†Test stopped.
‡In test.
§Still in first stage creep.

Impact Strength in Variou

Condition	Test and Direction
Hot rolled plate (8)	Standard* (L)
	Standard* (T
	Substandard†
	Substandard†
As-cast (9)	Standard* (L)
As-cast, annealed (9)	Standard* (L)

*Standard V-notch Charpy impact s
2.165 in.)
†Substandard V-notch Charpy spe
2.165 in.)



Effect of Temperature tion in Circulating Pres on Impact Energy to

Torsional Properties (9)

Condition	O.D.	I.D.	Modulus, × 10^6	Proportional Limit	0.2% Yield
Tubular Specimens					
Hot rolled	1.0112 in.	0.8135 in.	5.22 psi.	13,550 psi.	29,500 psi.
Hot rolled	1.0152	0.8138	5.22	13,700	28,300
Base annealed	1.0151	0.8135	5.24	17,850	29,800
Base annealed	1.0156	0.8139	5.29	19,450	32,100
Solid Specimens					
Hot rolled	0.4970	—	5.93	20,800	35,900
Base annealed	0.4970	—	6.13	22,000	33,600
Base annealed	0.4971	—	6.25	22,800	34,000

Transverse Stress-Rupture Properties (8)

Temp.	Stress to Produce Rupture in Indicated Time		
	1 Hr.	10 Hr.	100 Hr.
Annealed Sheet			
150° C.	35,200 psi.	32,500 psi.	30,000 psi.
230	28,000	26,000	24,000
345	22,200	22,000	21,800 est.
425	21,300	19,000	16,800
500	17,700	15,100	11,400
Cold Worked Sheet			
150	73,000	70,500	68,000
230	63,000	60,500	58,000
345	50,000	46,000	43,000
425	38,000	34,000	29,000
500	27,500	21,500	14,500

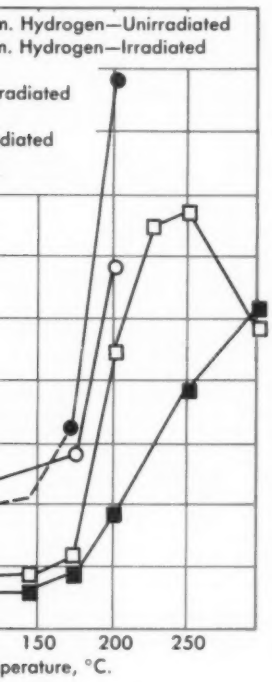
Equiaxed Alph 2 Held 8 Hr. Water Quench

Various Conditions (6)

T AND ECTION	IMPACT STRENGTH	
	ROOM	500° F.
d* (L)	4.0 ft-lb.	22.8 ft-lb.
d* (T)	2.0	12.8
dard† (L)	0.7	2.9
dard† (T)	0.4	3.1
d* (L)	6.0	23.3
d* (L)	5.0	45.0

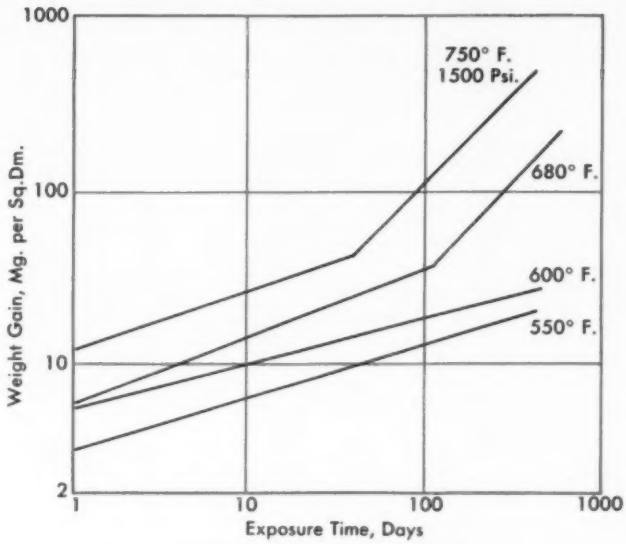
mpact specimen (0.394 × 0.394 ×

by specimen (0.200 × 0.200 ×



*ature and Irradia-
Pressurized Water
y to Fracture (6)*

Corrosion of Zircaloy-2 in High-Temperature Water and Steam (2)



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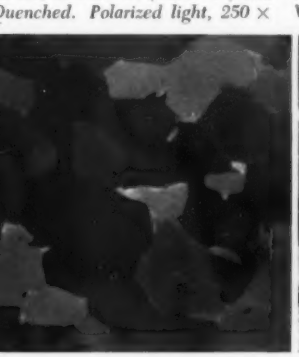
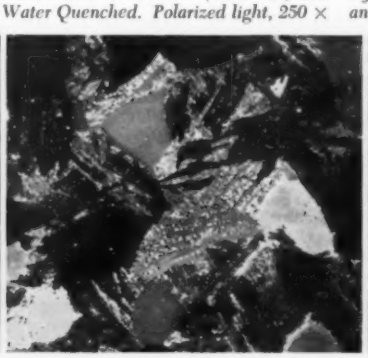
Typical Structures of Zircaloy-2

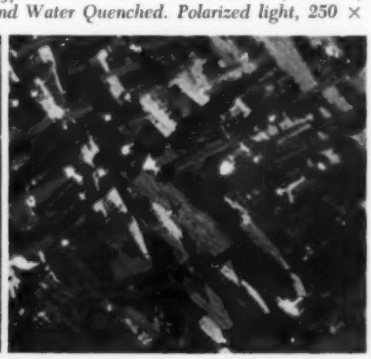
d Alpha Grains Typical of Zircaloy-8 Hr. at 700° C. (1290° F.) and Quenched. Polarized light, 250 ×



Alpha Grains in a Prior Beta Matrix Held 8 Hr. at 900° C. (1650° F.) and Water Quenched. Polarized light, 250 ×



Prior Beta Structure Shows Widmanstatten-Type Grains Held 8 Hr. at 1050° C. (1925° F.) and Water Quenched. Polarized light, 250 ×



Properties of Zircaloy-2

*By LESTER S. RUBENSTEIN**

Composition and General Properties

ZIRCALOY-2 is an alloy of zirconium produced by vacuum melting using the consumable electrode technique. The alloy has the following composition: tin, 1.20 to 1.70%; iron, 0.07 to 0.20%; chromium, 0.05 to 0.15%; nickel, 0.03 to 0.08%; zirconium, 97.87 to 98.65% (balance). The sum of the Fe, Cr, and Ni must fall within the range of 0.18 to 0.38% as determined from the average of all analyses for a single lot (1).

Zircaloy-2 is used primarily as cladding for nuclear fuel elements and for structural components in reactor cores. This use depends on its excellent corrosion resistance, low neutron thermal absorption cross section (0.22 barn) and structural stability at reactor operating temperatures. The alloy is allotropic and exists both in a high-temperature beta phase (b.c.c.) and a room temperature alpha phase (c.p.h.), and is capable of limited heat treatment. Zircaloy-2 can be fabricated by almost all metalworking operations but must be protected during welding by inert atmosphere boxes or efficient inert-gas shields because of its rapid rate of contamination with oxygen and nitrogen. Variation in impurities or additives can cause significant changes in corrosion resistance or mechanical properties.

*Bettis Atomic Power Laboratory, Westinghouse Electric Corp., Pittsburgh.

Physical Properties of Zircaloy-2

Numbers in Parentheses Refer to Sources of Information Listed Inside the Fold.

(11) Density at 20° C. (68° F.).....6.570 g. per cc. ± 0.0006
(12) Electrical resistivity at 21° C. (70° F.).....74 × 10^{-6} ohm-cm. (29 × 10^{-6} ohm-in.)

Elastic Properties (in Tension) (8)

CONDITION	TEST TEMPERATURE	ELASTIC MODULUS × 10^6	POISSON'S RATIO
Annealed	27° C.	13.9—14.3 psi.	0.368—0.380
Annealed	150	13.3—13.8	0.425—0.460
Cold worked	27	14.5	0.382—0.406
Cold worked	150	13.9—14.2	0.392—0.432

Thermal Conductivity (13)

TEMPERATURE	CAL./SEC./SQ.CM./° C./CM.	WATTS/SQ.CM./° C./CM.	BTU./HR./SQ.FT./° F./FT.
20° C.	0.0279	0.117	6.8
100	0.0287	0.120	6.9
200	0.0294	0.123	7.1
300	0.0306	0.128	7.4
400	0.0310	0.130	7.5
500	0.0322	0.135	7.8

Average Coefficient of Thermal Expansion Between 30° C. and Indicated Temperature

TEMPERATURE	IN./IN./° C. × 10^{-6}	IN./IN./° F × 10^{-6}
100° C.	5.84	3.24
200	6.00	3.33
300	6.15	3.42
400	6.30	3.50
500	6.47	3.59
600	6.61	3.67

Extrusion Constant at 1550° F. (16)

$K = 31{,}600$ psi. where: $K = \dfrac{P}{A_o \ln \dfrac{A_o}{A_i}}$

P = total press load (lb.).
A_o = area of container (sq.in.).
A_i = area of extruded shape (sq.in.).

Transformation Temperature Limits – Alpha Plus Beta Phase (15)

On heating: 815 to 830° C. (alpha/alpha+beta); 975 to 995° C. (alpha+beta/beta).
On cooling: 930 to 960° C. (beta/alpha+beta); 770 to 785° C. (alpha+beta/alpha).

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form
Stainless steels can be bent, drawn, and roll-formed by all the standard techniques known in the metalworking industry. In these operations, stainless requires somewhat greater power and harder tools than it takes to work softer materials. But this characteristic stems directly from stainless steel's superior ability to withstand bending and denting in service.
This attractive stainless cocktail set was produced by flow-turning—one of the newer metalworking techniques that
have been developed to offer new answers to many design problems. With these improved fabricating techniques, components that formerly called for two or more materials can often be made better or more economically from one solid material that fills all the requirements of design. The techniques of spinning and abrasive wheel polishing offer special design possibilities, as exemplified by the spun dish on page 7. For further information on the degree of forming possible with a specific type of stainless, contact your nearest A-L office.
Stainless Cocktail Set
Stainless Auto Heater

Sample pages from A-L's new free booklet on design

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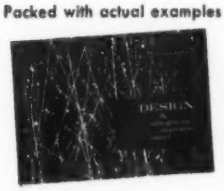
Write for your copy of "Design in Allegheny Stainless Steel"—without cost or obligation. *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa. Address Dept. MP-4.*

Packed with actual examples of good design—and ideas for future applications



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Circle 1318 on Page 48-A

954

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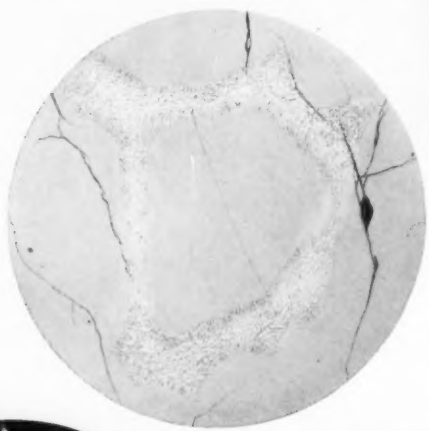
...Blue Ribbon Award Winners, 1959 A.S.M. Metallographic Exhibit



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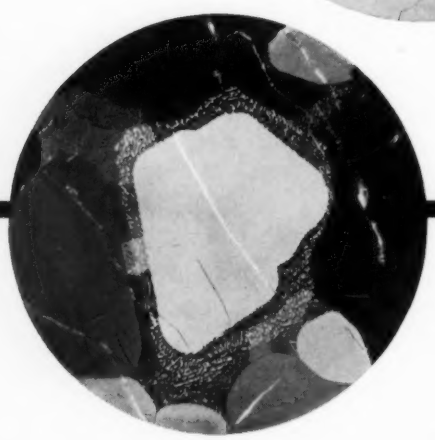

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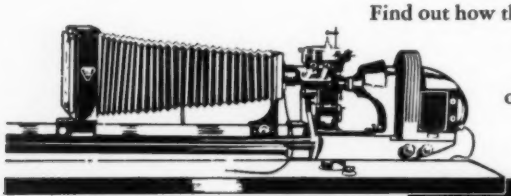

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Circle 1319 on Page 48-A

New Eddy Current Test for Tubing

*By BYRON B. BURD**

Small defects can be readily located in tubes by a new eddy current testing setup which contains circuitry that filters out background interference. Before being applied in regular production, this system processed well over 1,000,000 ft. of tubing, and consistently located defects of all sizes and types, both surface and subsurface. (S13h, 1-52; 4-60)

PRODUCERS AND USERS OF TUBING have long sought a practical and reliable method for nondestructive testing. To be useful, such a test has to meet stringent requirements. It must consistently reveal the presence of all harmful irregularities and their exact location. Information as to size (area and depth) of the flux is also essential.

Until recently, no tube testing method has been able to fulfill all of these requirements. In one way or another, every conventional system fell short. Though hydrostatic testing, along with dye penetrant, magnetic particle, ultrasonic, boroscopic, radiographic and visual inspection, provided important information, no one method was adequate by itself. With the 100% inspections and tight specifications required by users of tubing in the atomic energy and missile fields, there was great need for a better way of testing. We believe this has been answered by a new eddy current testing setup we call "Damascope". It is being employed for regular production inspection on welded tubing.

The heart of this new testing method is a "Radac" multiple frequency electromagnetic unit developed by Metrol, Inc. This method, which employs modulation analysis, is a distinct improvement over several earlier eddy current test devices. In those, background interference caused by innocuous variations in the tube often masked separate responses due to defects. In our system, however, through proper adjustment of the special circuitry, background interference is filtered out, and only the response caused by the defect is registered. This allows flaws and other undesirable irregularities to be positively located. Figure 1 illustrates the tester in action.

As to actual operation, eddy currents are induced in the tube being tested by a radio-frequency field. These currents explore the entire tube wall, including both inside and outside diameter, for the full length of the tube. When a defect passes through the coil, it disturbs the eddy current pattern. Holes, laps, seams and porous areas are thus located and defined.

A single sensing head permits two-channel operation, with the differential channel being selectively sensitive to discontinuities. The ab-

*Chief Metallurgist, Damascus Tube Co., Greenville, Pa.

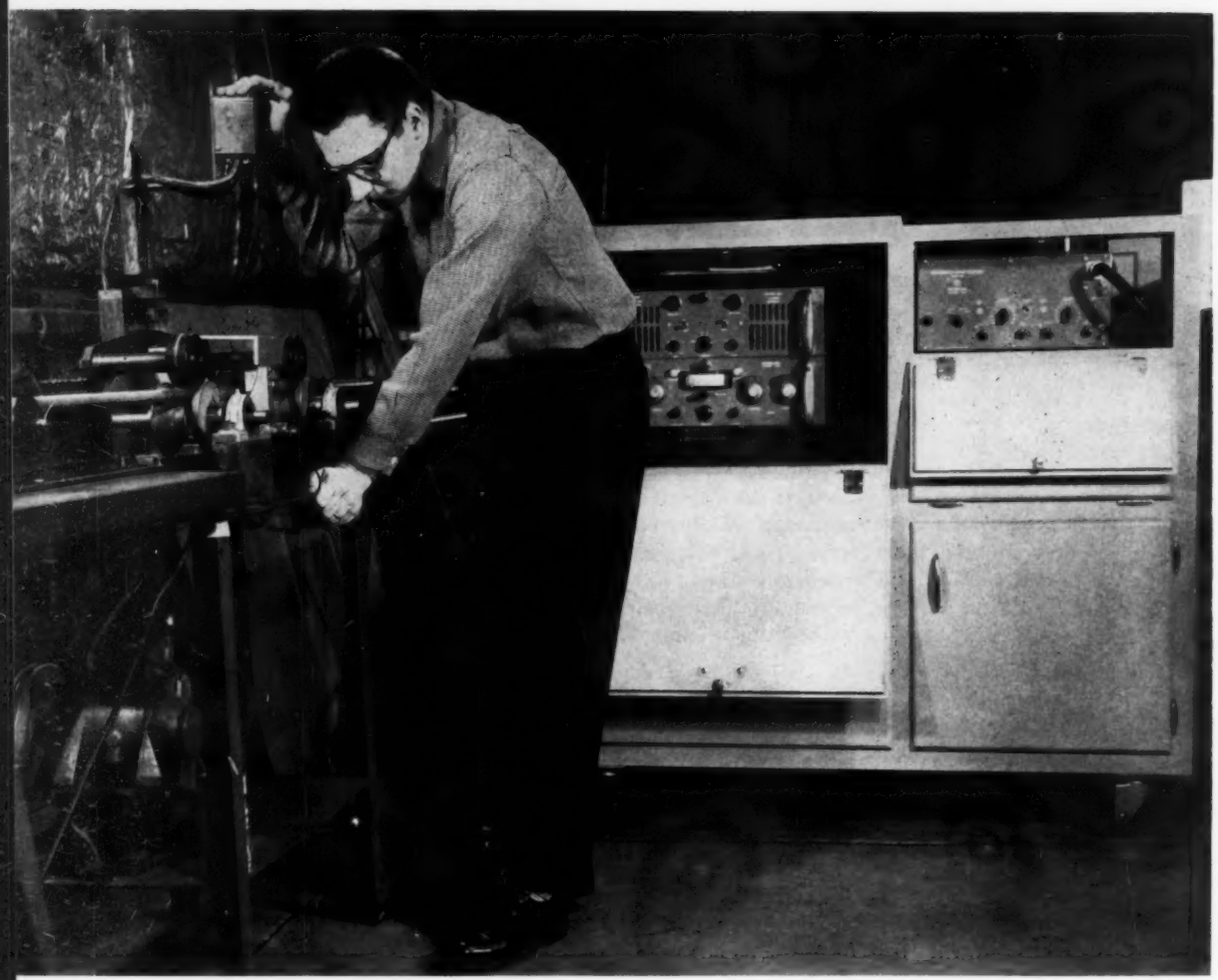


Fig. 1 – Damascope in Action. Eddy currents probe the entire tube wall, inside and out. When a defect passes, a tone alarm sounds, a red light blazes, and paint splashes on the defect. Occurrence of the defect is also recorded on an adjacent chart

solute channel is sensitive to variations in dimensions or metal properties, and the outputs of both are recorded simultaneously on a dual channel recorder. Through suitable controls linked to the eddy current instrumentation, these irregularities are revealed and defective tubing is rejected.

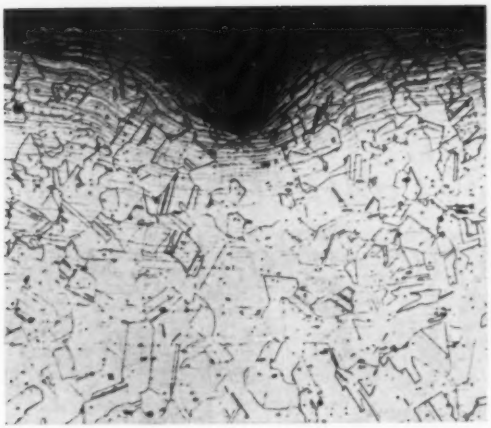
Rejection is electronically controlled, and is independent of human skill or judgment. When the equipment discovers a flaw it is signaled to the inspector by a loud alarm and a red light. Meanwhile, location of the flaw is automatically marked with red dye, and an inked record is made on the test chart.

A.S.T.M. Specifications Met

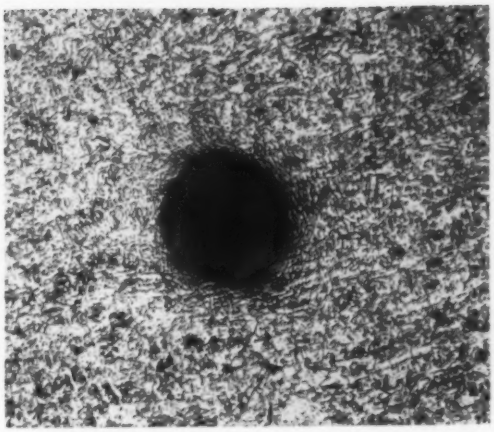
For production-line inspection of tubing, Damascope can be calibrated to reveal any irregularities as small as those listed in Table I, which is outlined in a 1959 revision of A.S.T.M. Standards.

An important advantage: The tester, although originally developed for welded tubing, functions equally well on pierced, extruded or centrifugally cast material. Thus, the tubing user may now order to a specification based entirely upon quality, irrespective of the method of manufacture.

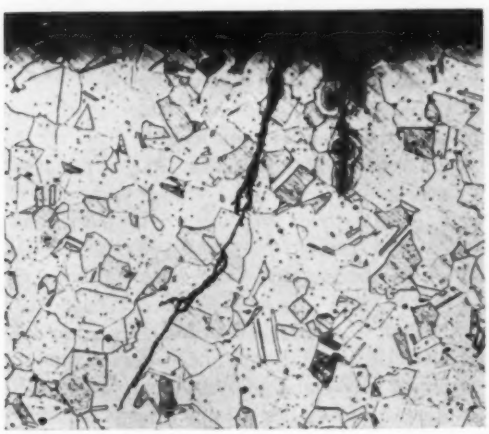
In development, well over 1,000,000 ft. of tubing were inspected by this method before



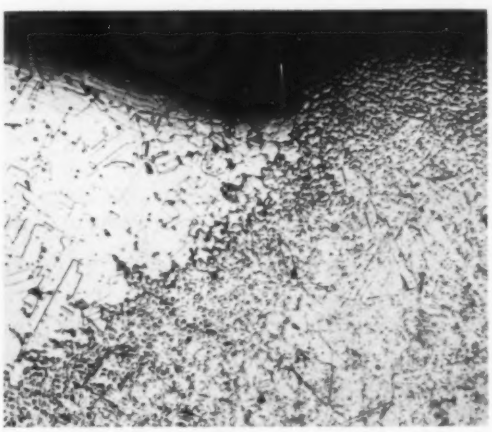
An Inside Diameter Indentation, 0.008 In. Deep



A Blowhole in a Weld, 0.0075 In. Diameter



A Stress-Corrosion Crack, 0.021 In. Deep, on the Inside Diameter



An Undercut, 0.0047 In. Deep, on the Inside Diameter

Fig. 2 – Several Types of Defects Located by the Eddy Current Tester. Types 304 and 316 stainless steel are represented. 100 ×

it was put into regular production inspection. During this period, the new system consistently supplied accurate data on size and location of laminations, and other potentially dangerous defects. Some defects are shown in Fig. 2.

Table I – Permissible Sizes of Tubing Defects

Wall Thickness	Minor Dimension of Defect (Length or Depth)	Area of Defect
0.035 in.	0.005 in.	0.0020 sq.in.
0.049	0.006	0.0024
0.058	0.007	0.0028
0.065	0.008	0.0032
0.072	0.009	0.0036
0.083	0.010	0.0040

In actual test, our machine has been able to pick out flaws not revealed by other testing devices. For example, tube lengths of Zircaloy-2 were recently submitted to us for inspection. They had been passed as sound, but because they were to be used on a nuclear reactor, the user wanted absolute proof of their quality. In every one of these tubes, subsurface flaws were indicated. These were subsequently found on sectioning and microscopic examination. Gas pockets, located well beneath the surface were present – the tubes were faulty although rigorous testing by other methods by the user and the manufacturer had failed to indicate this.

Chromium Steels Remain Tough After Eight Years at High Temperature

*By MERRILL A. SCHEIL**

Results of an unprecedentedly long series of exposure tests in operating equipment at 715 and 900° F. verify generally the conclusions reached 25 years ago from corrosion and stress-corrosion tests in the laboratory, and from a 15 months' run in petroleum equipment. (Q26s, R7a, N8; SS)

ONE OF THE EARLIEST AND LARGEST commercial applications of the new stainless irons was by the petroleum industry, starting in the 1920's. Many refinery vessels were lined with the 17% chromium-iron (Type 430). As noted in the early 1930's by E. S. Dixon in "The Book of Stainless Steels", p. 583: "They were noncorroding and nonscaling; nevertheless they were extremely brittle when cold and were removed from service." While the high chromium-irons or ferritic alloys remained tough after heating at 1250° F. or higher, and at 650° F. or lower, when they were heated even a few months at 700 to 1000° F. and then cooled, the room-temperature tests showed very low impact values. This so-called 885° embrittlement has received much study, but so far as the present author knows, no adequate and complete explanation has been advanced. Like the temper brittleness of certain engineering alloy steels, it is still an unsolved metallurgical mystery.

Since the damaging embrittlement seemed to depend on the chromium, it was early proposed that an alloy lower in chromium be used. However, the designer faced a dilemma: The chromium could not be reduced so far as to lose necessary corrosion resistance nor get into the region of hardenable alloys which could not be fabricated and welded with safety. Walking this tightrope, Type 405 stainless (11.5 to 14.5% Cr, 0.08% max. C, 0.10 to 0.30% Al) was introduced as linings of oil refinery vessels in 1936 with the greatest of success. A 1947 article by the author† indicates that 10 to 12 years of experience had developed very little trouble in the service of hundreds of such pieces of equipment. Of the many modifications of the general type which had been proposed, such as those containing minor amounts of molybdenum, nitrogen, titanium, or columbium, we at A. O. Smith preferred a 0.20% aluminum

*Director of Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis. Several men in the A. O. Smith Corp. Metallurgical Research Department were responsible for conducting the tests that are reported here. The author would like to acknowledge Murray Siegel, Tom Jones and Thomas R. Gaulke for their reports which contain the data on which this article is based.

†"Modified Type 405 Stainless Iron – a Satisfactory Lining for Petroleum Refinery Vessels", by Merrill A. Scheil, *Metal Progress*, July 1947, p. 91.

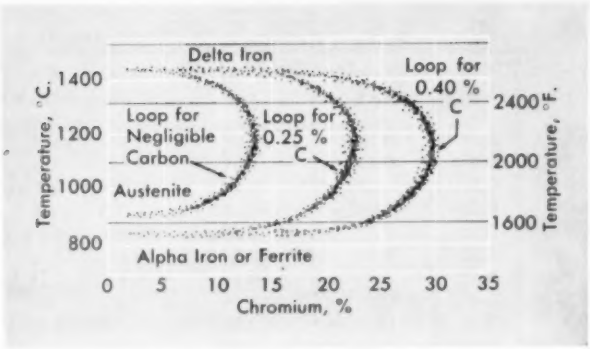


Fig. 1 – Diagram, According to E. C. Bain, Showing the Influence of Carbon on the Austenitic or "Gamma Loop" in the Structural Diagram of the Fe-Cr Alloys. (The Book of Stainless Steels)

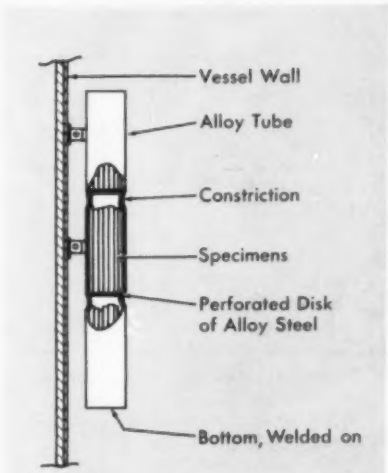


Fig. 2 – Cutaway Sketch of Alloy Tube Containing Three Sets of Specimens, and Its Attachment to the Vessel Wall

addition to suppress the air hardening tendency of the steel, a somewhat lower chromium content than in standard Type 405 – 11 to 13% – and a rigid exclusion of titanium and columbium. Huey corrosion tests and stress-corrosion tests in various heat treated states and in weldments gave results on this modified Type 405 which were quite comparable to the 17% Cr alloy, even though it was a common belief that corrosion resistance and heat resistance varied directly with the chromium content.

As a matter of fact, R. H. Thielemann* had pointed out in 1940 that the alloying and incidental elements in a steel had certain effects (which could be estimated quantitatively) of either forming or suppressing austenite in the alloy when at annealing temperatures – say 2000° F. As shown in Fig. 1, a "gamma loop" exists in the iron-chromium binary system, which means that at 2000 to 2100° F. all alloys are completely austenitic up to about 13% chromium. A 13% Cr iron with 0.10% C, however, would contain some ferrite or delta iron at those high temperatures – the carbon appeared to counteract some of the chromium and form ferrite (alpha or delta iron). On the other hand, a 15% Cr iron would be completely austenitic if it had 0.2% Al (aluminum being an austenitizing element). The chromium equivalents suggested by Thielemann are as follows:

Ferrite Formers		Austenite Formers	
Carbon	−40	Tungsten	+ 2.1
Nickel	− 3	Tantalum	+ 2.8
Manganese	− 2	Molybdenum	+ 4.2
Copper	− 1	Columbium	+ 4.5
		Silicon	+ 5.2
		Titanium	+ 7.2
		Vanadium	+11.0
		Aluminum	+12.0

On the basis that a wholly austenitic steel would not transform at temperatures and compositions within the gamma loop and therefore would not embrittle in high-temperature service, it occurred to us that this concept of chromium equivalent could be used to predict the embrittlement of various Type 405 stainless alloys, and in 1951 the author reported† studies on nine such materials which had been inside operating refinery equipment at 715 and at 900° F. for more than a year. Judging embrittlement mainly by loss in Charpy impact, the conclusions then were that embrittlement of such steel *can* be predicted on the basis of its chromium equivalent. The steels which were below 13% chromium equivalent remained notch tough and those approaching 15% were embrittled after exposure at 715 and 900° F. There were also indications that 0.5% Mo stabilizes the carbide, slows down carbide precipi-

*"Some Effects of Composition and Heat Treatment on the High-Temperature Rupture Properties of Ferrous Alloys", by R. H. Thielemann, *Proceedings*, American Society for Testing Materials, 1940, p. 788.

†"Embrittlement of 12% Cr Steels After Exposure to 750 and 900° F.", by Merrill A. Scheil, American Society for Mechanical Engineers, 1951 paper No. 51-A-97.

Table I – Analyses and Properties of Steels in Test Program

	A	B	C	D	E	F	G	H
Type	410+Mo	410 (L.C.)	405+Mo	405	9 Cr, 1 Mo	405 Mo(L.C.)	410	405
Cr Equivalent	8.79	10.68	13.45	15.01	11.14	15.72	10.22	12.11*
Analysis								
Carbon	0.13	0.028	0.08	0.05	0.10	0.04	0.07	0.08
Manganese	0.38	0.64	0.56	0.48	0.44	0.54	0.40	0.61
Phosphorus	0.012	0.016	0.014	0.010	0.010	0.010	0.014	0.018
Sulphur	0.038	0.020	0.009	0.005	0.015	0.025	0.023	0.017
Silicon	0.16	0.27	0.29	0.58	0.77	0.35	0.50	0.40
Chromium	12.20	11.74	11.59	12.55	8.16	13.89	12.45	12.26
Nickel	0.24	0.02	0.20	0.12	—	0.18	0.41	0.11
Molybdenum	0.58	—	0.54	—	0.92	0.14	—	—
Aluminum	—	—	0.25	0.23	—	0.22	—	0.21
Nitrogen	0.046	0.028	0.017	0.030	0.022	0.024	0.043	0.041*
Mechanical properties before exposure								
Annealed condition – Treatment I								
0.2% offset	41,200	30,400	39,600	43,900	57,100	43,100	47,600	40,300
% elongation	30.5	37.0	36.5	35.0	30.5	37.0	37.0	35.5
Charpy	32.3	15.4	40.0	41.5†	53.9	30.2	56.5	53.6†
Hardness	B-84	B-71	B-76	B-79	B-89	B-77	B-82	B-79
Grain size	8	4 to 5	5	4 to 5	6	4 to 5	9	8
Cold worked condition – Treatment II								
0.2% offset	97,400	72,250	76,000	87,000	95,300	82,800		
% elongation	12.5	16.5	16.0	14.0	17.0	14.0		
Charpy	41.9	3.5	39.5	23.8	29.9	11.5		
Hardness	B-96	B-86	B-89	B-93	B-97	B-92		
Grain size	8	5	5	5	6	4 to 5		
Coarsened condition – Treatment III								
0.2% offset	130,000	31,700	32,600	35,200	—	35,900	Decarburized	29,100
% elongation	7.0	36.0	32.0	31.5	9.0	34.0	Decarburized	36.5
Charpy	4.3	7.4	43.4†	5.1	12.6	15.7	Decarburized	56.4†
Hardness	C-44	B-72	B-66	B-74	C-34	B-74	Decarburized	66
Grain size	4 to 5	4 to 5	4 to 5	4 to 5	4	4 to 5	Decarburized	2

*After decarburization to 0.015% C, nitrogen was 0.050 and chromium equivalent 14.7.
†Notched parallel to rolled surface. Others notched perpendicular to rolling direction.

tation and suppresses embrittlement. The very low-carbon alloys appeared to embrittle after 715° F. exposure but did not at 900° F. The only observable change in microstructure for these alloys was a fine precipitation of carbides from the chromium ferrite after exposure at 900° F.

It should be emphasized that the stability of any steel in a particular test depends not only upon its chemical composition (chromium equivalent) but also upon its prior treatment.

Long-Time Tests

The above results were in the nature of preliminary findings. Several sets of samples were placed inside equipment in petroleum refinery service and for the 1951 results only one set of samples was removed from the stream. Subsequently several other sets were removed at intervals. The present report summarizes the entire findings on samples removed at intervals during tests at 715° F. lasting 55,600 hr. (6.3 years) and tests at 900° F. lasting 74,150 hr. (8.5 years). We believe that the results are unique and of importance in any long-range planning.

Eight commercial steels (Code A to H in Table I) were sent to us by our suppliers either as billets, bars, or heavy plate, enough to forge and machine 39 specimens from each. The shapes of the specimens were such that one round tensile bar (0.505 in. diameter) and three standard keyhole Charpy bars could be machined therefrom. One third of the specimens were annealed 1 hr. at 1550° F. and furnace cooled (Treatment I); one third were annealed 1 hr. at 1500° F., furnace cooled, and cold reduced under the hammer 10 to 15% (Treatment II) to simulate the cold rolled sheet sometimes used for field repairs; the remainder were grain coarsened by heating 1 hr. at 2000° F. and furnace cooled (Treatment III) to simulate the

effect of hot work during fabrication, and to give hardness and grain size approximately equal to that of the heat affected zone alongside welds. Microscopically, this latter shows up as an increase in the amount of alpha solid solution and a corresponding decrease in the number of carbide particles.

An exception to this routine was Steel H, Type 405: Half of the specimens were decarburized to 0.015% C. by heating in wet hydrogen at 2200° F. (Treatment IV). The purpose of the decarburizing treatment was to change the alloy from a somewhat hardenable type to a nonhardenable type. By removing carbon, the alloy composition would have a higher chromium equivalent (outside the gamma loop) which would also be equivalent to having actually a higher chromium content. Since the chromium content was considered critical for high-temperature aging embrittlement, this treatment would result in one alloy with both a high and a low chromium equivalent but identical otherwise and it should serve as a check for embrittlement with chromium above and below the critical analysis. The bars were punch numbered on the ends; corners and edges were also chamfered and length varied slightly according to code so any sample could be positively identified even if the punch marks were obliterated. (They were not.)

Steels Studied – Chemical analyses of the steels are given in Table I. The reasons for their inclusion in the test are briefly as follows:

Steel A, Type 410 + Mo, Cr equivalent 8.79, to find out whether an alloy well within the gamma loop will or will not be embrittled if it contains 0.5% molybdenum.

Steel B, Type 410 low-carbon, Cr equivalent 10.68, a steel within the gamma loop (even though it coarsens at forging temperature) – to find out whether the chromium associated with chromium as carbide in steel of normal carbon content will act differently toward embrittlement.

Steel C, Type 405 + Mo, Cr equivalent 13.45, to verify preliminary tests which showed that this steel is free from 885° embrittlement up to 5000 hr. (208 days) exposure, provided it had not previously been coarsened by heating above 2000° F. This steel corresponds to a variety used by A. O. Smith since the mid-1930's.

Steel D, Type 405, Cr equivalent 15.01, near the top limits desired for carbon and chromium and well outside the gamma loop – to test its stability during long exposures.

Fig. 3 – Flame Cut Container Showing Excessive Coking Within the Tube

Steel E, a proprietary alloy "Sicromo", Cr equivalent 11.14, extensively used as tubing – to verify its reputation that the 1% Mo helps retain ductility during long exposure.

Steel F, a low-carbon Type 405, with Mo and Cr on the high side, Cr equivalent 15.72, well outside the gamma loop. Its Charpy impact of 30 ft-lb. in the annealed condition is reduced to 12 ft-lb. by 10 to 15% cold working. It was included to verify the expectation that this steel would embrittle on exposure and should therefore be avoided for high-temperature service.

Steel G, Type 410, Cr equivalent 10.22, was to be tested in the 715° program only. Its analysis was such that it was expected to retain its toughness.

Steel H, Type 405, Cr equivalent 12.11 before decarburization and 14.71 after decarburization, was to be tested in the 900° program only to study the effect of variable carbon on an alloy of otherwise identical analysis and regarded as favorable.

At this point it might be remarked that some of our early expectations were not verified.

Test Program – One bar from each steel in each condition (19 in the group for testing at

Code	Steel	Chromium Equiv.	Treatment (a)	0.2% Offset (c)			% Elong.			Charpy			B Hardness		
				A (b)	B (b)	C (b)	A	B	C	A	B	C	A (b)	B (b)	C (b)
A	410 + Mo	8.79	I			46/47			33/34		39/33				81/84
			II			86/84			18/22			30/29			95/97
			III			93/46			18 22			23/22			95/98
B	410 (L.C.)	10.68	I		37/46			30/25		11/4				71/79	
			II			62/66			16/18			4/3		83/89	
			III		36/42		36/28			8/3				69/79	
C	405 + Mo	13.45	I			49/52		34/30			57/45			78/84	
			II			71/73			19/22			29/31			89/92
			III			41/44			33/32			27/26	72/82		
D	405	15.01	I	58/70				32/28		30/6			84/93		
			II		81/86				21/20	20/4				92/97	
			III			52/56			30/28		3/2		81/88		
E	"Sicromo" 9Cr, 1Mo	11.14	I	58/68				34/28			53/48				89/91
			II			88/86		20/24				43/50			95/96
			III			132/132			16/14			41/41			105/107
F	High Cr 405 + Mo (L. C.)	15.72	I	60/73				31/26		30†/2			83/94		
			II	83/93					18/18	11†/2				93/99	
			III		58/64				28/26	46†/2			83/93		
G	410	10.22	I	55/69				36/32		57/36				85/91	

(a) I Annealed 1 hr. at 1550° F., furnace cooled, 75° F. per hr.
II Same, cold worked 10 to 15%.
III Grain coarsened, 1 hr. at 2000° F., furnace cooled, 100° F. per hr.
IV Decarburized, cold worked, grain refined at 1600° F.

(b) A is embrittled, scores zero.
B is slightly embrittled, scores one.
C is not embrittled, scores two.

(c) In 1000 Psi. *Estimated value replacing erratic test. †Value for unexposed sample.

Fig. 4 – Embrittlement by Long Exposure at 715° F. Figures are results after 19,500 hr. and 55,600 hr., respectively

715° and 20 in the group for testing at 900°) were bundled and placed in the bottom compartment of a container as shown in Fig. 2. Then a perforated plate was placed on the crimping and a second set of specimens inserted. Finally each container contained three sets of samples. The ends were closed with perforated plates, welded on. The surrounding tubes were of 5% Cr steel, 40 in. long and 5 in. O.D. In this arrangement each year's test specimens are removed during a routine shutdown of the equipment by cutting off a third of the length of the tube, starting at the bottom section. Conditions of exposure were such that the tube rapidly was filled with coke (Fig. 3).

Tests at 715° F.

The specimens were exposed at 710 to 715° F. and 25 psi. pressure in a separator at the Borger District, Phillips Petroleum Co. The experiment started on September 7, 1948. The Phillips Petroleum Co. deserves our thanks for their help in this long program. The test specimens were taken out of the chamber after 1.6 years, 2.3, 3.6, 4.5, 5.5 and 6.4 years. Comparisons of the original mechanical properties and those after 1.6 years' exposure were presented to the A.S.M.E., as noted above, in 1951. Tension and Charpy keyhole notched specimens were machined from the exposed samples and tested

Total			Score (b)	Individual Rating	Over-All Rating
A (b)	B (b)	C (b)			
0	1	3	7	Excellent	7.7 Best
0	0	4	8	Excellent	
0	0	4	8	Excellent	
1	3	0	3	Fair	4.0 Fair
0	1	3	7	Excellent	
2	2	0	2	Poor	
0	3	1	5	Good	6.3 Very Good
0	0	4	8	Excellent	
1	0	3	6	Very good	
3	1	0	1	Poor	3.3 Fair
1	2	1	4	Fair	
1	1	2	5	Good	
1	2	1	4	Fair	6.3 Very Good
0	1	3	7	Excellent	
0	0	4	8	Excellent	
3	1	0	1	Poor	2.3 Poor
2	1	1	3	Fair	
2	1	1	3	Fair	
2	2	0	2	Poor	2.0 Poor

by us in Milwaukee. These tests include room-temperature impact testing (three tests), a tension test, hardness and microstructural surveys. At the end of the program, curves were drawn showing the trend of each measured property with time.

In the great majority of instances, the points so located could be plotted as a smooth curve or trend line without having any point so far from the curve as to be beyond expected variation, sample to sample, in any supposedly duplicate test. This is especially true of the trend lines showing effect of exposure after 19,500 hr., and up to 55,600 hr., and these trends are therefore shown by the data on Fig. 4. Changes in the unexposed samples can be computed easily by comparing appropriate values given in Table I and in Fig. 4.

Inspection of the curves and complete data show that some of the steels did not change after six years of exposure. Some did embrittle slightly and others embrittled to a great extent. In this context "embrittlement" is defined by a change in one or more of these properties:

1. Increase in yield strength (0.2% offset, in our present presentation).
2. Decrease in ductility (% elongation in 2 in.).
3. Decrease in impact energy (Charpy keyhole test at 70° F.).
4. Increase in hardness.

The tendencies of the steels to embrittle in such ways were rated and noted in tabular form in Fig. 4, showing each steel in each heat treatment and condition. The categories employed for our ratings were A, embrittled; B, slightly embrittled; and C, good (did not embrittle). The number of times a specific steel fell in each category was totaled and a point system was applied. An embrittled steel received zero points, slightly embrittled one point, and two points for a steel that was rated good. Therefore, the maximum points for a steel in a specific condition is eight, which results from receiving two points for each of the four properties tested.

It is recognized that such a definition of embrittlement will be accepted with reservation by many readers. For example, some will undoubtedly put more emphasis on a loss in impact energy than an increase in hardness. It is now recognized that chromium steels are temperature-sensitive. In our program all data on Charpy keyhole notched specimens were determined at room temperature. This is not the most favorable testing temperature; increasing the testing temperature would have resulted in higher energy values for some of the steels. We now know that a more concise method of evaluating the aging effect on notch toughness would have been to determine the energy-temperature curve of each steel and then set the temperature for an arbitrary energy value. The aging effect would then amount to the increase in temperature required to obtain the arbitrary value of energy after exposure.

Again, since hardness, strength and ductility are fairly closely related, our method of appraisal by total score seems to give two or three times as much weight to tensile properties

Code	Steel	Chromium Equiv.	Treatment (a)	0.2% Offset (c)			% Elong.			Charpy			B Hardness		
				A (b)	B (b)	C (b)	A	B	C	A	B	C	A (b)	B (b)	C (b)
A	410 + Mo	8.79	I		44/50				29/29			37/44			82/85
			II		80/85				18/21			39/40			95/93
			III	44/54					24/26			25/24			96/93
B	410 (L.C.)	10.68	I			36/37		34*/30				10/14			68/66
			II			54/56			19/20		5/4				82/81
			III		32/39				34/32			7/15			68/66
C	405 + Mo	13.45	I			44/47		36/32				37/46			79/79
			II		62/70				23/21			39/58			87/89
			III	32*/42					32/30			29/40			74/72
D	405	15.01	I		44/52		36/25				29/22				80/80
			II			64/67		24/19		13/7					88/89
			III		36/44				35/32			19/22			74/76
E	"Sicromo" 9 Cr, 1 Mo	11.14	I		57/66			32/28		44/32					86/82
			II			82/69			22/20	37/21					96/96
			III		108/115				20/17	39/24					104/102
F	High Cr 405 + Mo (L. C.)	15.72	I		45/52			32/28			30/22				80/81
			II	68/89					19/18			3/4			90/89
			III	49/59					26/24			2/3			86/84
H	405	12.11	I		44/52		36/28				34/44				80/81
		14.71	IV		30/35		40/32			15/9					65/66

(a) I Annealed 1 hr. at 1550° F., furnace cooled 75° F. per hr.
II Same, cold worked 10 to 15%.
III Grain coarsened, 1 hr. at 2000° F., furnace cooled, 100° F. per hr.
IV Decarburized, cold worked, grain refined at 1600° F.

(b) A is embrittled, scores zero.
B is slightly embrittled, scores one.
C is not embrittled, scores two.

(c) In 1000 Psi. *Estimated value replacing erratic test. †Value for unexposed sample

Fig. 5 – Embrittlement by Long Exposure at 900° F. Figures are results after 21,300 hr. and 74,150 hr., respectively

as to notch toughness. However, the skeptical reader can make his own assessment of the data given in Table I and Fig. 4 and come up with his own conclusions. We believe they will not be far from ours.

These conclusions are:

1. Type 410 + Mo showed the best "anti-embrittlement" characteristics – that is to say the steel did not harden, strengthen or lose impact strength. The low chromium equivalent of this steel plus the addition of molybdenum suggests that alloys entirely in the gamma loop will remain tough. One difficulty would be the rather high carbon in this alloy which makes it objectionable for welding because of the high hardenability of the heat affected zone.

2. Types 405 + Mo and "Sicromo" gave next best results, and can be expected to give very good service at 715° F.

3. Types 405, 405 + Mo (high Cr) and 410 were embrittled at 715° F. – severely in some physical conditions.

4. The annealed plus cold work condition, Treatment II, has better "anti-embrittling" properties than the other two treatments. The annealed condition usually embrittled most severely.

5. There is some doubt that there is a close relationship between chromium equivalence

Total			Score (b)	Individual Rating	Over-All Rating
A (b)	B (b)	C (b)			
0	1	3	7	Excellent	
0	1	3	7	Excellent	6.7 Very good
1	0	3	6	Very good	
0	1	3	7	Excellent	
0	1	3	7	Excellent	7.0 Best
0	1	3	7	Excellent	
0	1	3	7	Excellent	
0	1	3	7	Excellent	6.7 Very good
1	0	3	6	Very good	
1	2	1	4	Fair	
1	1	2	5	Good	5.3 Good
0	1	3	7	Excellent	
1	2	1	4	Fair	
1	0	3	6	Very good	5.0 Good
1	1	2	5	Good	
0	3	1	5	Good	
1	0	3	6	Very good	5.7 Good
1	0	3	6	Very good	
1	2	1	4	Fair	3.5 Fair
2	1	1	3	Fair	

and resistance to embrittlement at 715° F. While the steels with equivalent of 15 or more were embrittled, the best of the steels had a low equivalent (8.79), and Steel G, a Type 410 of 10.22 chromium equivalent, rated the poorest of those tested. While the rating given for Steel G is poor, its elongation and Charpy value after the exposure period are considered equal to other alloys rated "good". (It must be remembered that the ratings are based on the *trend* of the change and not on the actual value after exposure.)

The writer believes that there should not be any borderline figure. The most that can be said is that the higher the chromium equivalent the greater will be the tendency toward embrittlement. The main discrepancy in this statement is Code G, the Type 410 steel mentioned above with chromium equivalent of 10.22. This steel was tested in only one condition – annealed. Type 410 L.C. (Code B) has approximately the same chromium equivalent, and its rating is "Fair". However, the rating attained by this steel in the annealed condition is only 3, almost the same as Steel G with rating of 2. It was also stated that the annealed condition embrittled the most. Therefore, it may be possible that the rating of the questioned steel might be improved if the grain coarsened and the annealed plus cold work conditions were also tested.

The high performance of Code E, "Sicromo", may be explained by its chemical analysis. Its chromium content is 8.16%, the lowest of all those tested. From this it could be stated that it has less chromium to cause embrittlement. The higher chromium equivalent (11.14) is due to high silicon and molybdenum contents.

The second modification of the idea that chromium equivalent is a good signpost is that different *types* of steels cannot be judged by their chromium equivalent – that is, a Type 405 should not be compared with a Type 410. Comparisons should be made within a steel's own type. This is indicated below:

Type 410			Type 405		
Code	Cr Equivalent	Rating	Code	Cr Equivalent	Rating
A*	8.79	7.7	C*	13.45	6.3
G	10.22	2.0	D	15.01	3.3
B	10.68	4.0	F	15.72	2.3

*Contains 0.5 molybdenum.

Tests at 900° F.

Specimen assemblies shown in Fig. 2 were sent to the Shell Oil Co. at Wood River for exposure at 900° F. Twenty specimens were returned each year for five years and the last after 8.5 years. We wish to acknowledge their help in this program. Tensile and three impact specimens were machined from each bar, exactly as indicated in the 715° program, and tested at room temperature.

When the results were plotted against time, several of the curves showed important changes during the first 2.4 years. It was almost as though this long stay at 900° had relaxed internal stresses. Almost without exception, however, definite and smooth-trend curves could be drawn for the changes occurring after this first

period. Consequently the data in Fig. 5 note properties after 2.4 years and 8.5 years of exposure. Information about the magnitude of the earlier changes can be had from the data in Table I.

Using the criteria defined in the discussion of the 715° tests we conclude that:

1. None of the steels (except Code H) became embrittled after years of exposure to 900° F. Condition I, assigned a rating of fair, could be questioned because of the favorable elongation and Charpy value after the exposure period.

2. Types 410 + Mo, 410 (L.C.), and 405 + Mo showed the best "anti-embrittlement" characteristics.

3. Type 405 Code H steel in the annealed or decarburized condition rated only "fair" in its resistance to embrittlement. In fact it is rated 3.5, the most embrittled.

4. Steels coded D, E and F are rated "good" and have a slight tendency for embrittlement. In each instance the annealed state embrittled most, but when the grain had been coarsened it was "good" to "excellent". In fact it might almost be stated that grain coarsening decreases the tendency of 12% chromium steels to embrittlement when operating at 900° F.

5. There seems to be little relationship between chromium equivalent and embrittlement at 900° F., inasmuch as Codes A to F are rated "good" or better, and any of them doubtless could be used with complete satisfaction after a recommended heat treatment, yet the chromium equivalent ranges from 8.79 to 15.72.

6. Comparing the original microstructure and that obtained after 8.5 years of exposure did not show much change, except that Steel H in Treatment IV coarsened considerably. Another steel that coarsened to a smaller extent was Code B, 410 (L.C.) in the annealed and the annealed plus cold worked conditions.

Conclusions

It is satisfying to note that, in general, the conclusions we reached 25 years ago about the suitability of Type 405 steel containing molybdenum and with chromium on the low side — conclusions reached by a fairly short series of laboratory experiments — have been verified by this series of tests, unprecedented as to duration. Our worry that it (Code C) might not serve so well if it had previously been coarsened by heating at 2000° F. was dissipated by the long tests — it rated as "very good" in this condition both after 6.5 years at 715° F. and after 8.5 years at 900° F. In general, conclusions reported after 15 months' exposure were confirmed by extending the tests for several years. We are now less intrigued by the "chromium equivalent" than we were then; the early indication that the steels with a high value would be embrittled at 900° F. is not borne out in every one of the heat treatments examined by the tests extending to 8.5 years. Likewise the *very* low-carbon alloys in the annealed condition show an embrittling tendency at both 715 and 900° F. On the other hand, the low-chromium, high-molybdenum "Sicromo" performed well, as indicated by its good history as tubes in similar services.

Code B steel, a low-carbon Type 410, was selected to learn more about the effect of carbon in releasing chromium for embrittlement. At 715° F. the Charpy data indicate a low level of energy after 6.5 years while at 900° F. the energy values are increasing from a lower value after 2.2 years to a value nearly the same as the original after 8.5 years. Thus it would appear that the embrittling tendency of a low-carbon chromium steel is greatest at the lower end of the embrittling range with 900° F. being the upper limit. There is a definite trend here for self-healing on "overaging" at 900° F. on longer exposure.

Code D steel, a Type 405 with 0.05% carbon and 12.5% chromium, which had been considered as the top limit for a nonembrittling 12% Cr steel of 0.08% max. carbon, showed definite tendency to remain embrittled at 715° F. in all conditions of heat treatment. Exposure at 900° F. improved notch toughness after the grain coarsening treatment. This would indicate that grain structure is more important at 900° F. than is the chromium equivalent.

Code F steel, with 0.04% carbon and 13.89% Cr, like Code D steel, has a high chromium equivalent placing it well outside the gamma loop. There is no doubt that 715° F. is a bad embrittling temperature for this steel as the Charpy tests show no increase in energy value during the exposure period. At 900° F. this steel could be judged to have embrittled in two of its heat treated conditions if we compare energy values unexposed with those after 2.4 years. In the annealed condition, Code F steel is showing slight embrittling tendencies. The indications for high chromium equivalent steels are very definite embrittling tendencies at 715° F., while at 900° F. this tendency is affected by prior heat treatment.

Producing for the Supersonic Age

Flight in the Thermosphere—II

Materials for Nonmelting Heat Sink Systems

*By WILLIAM S. PELLINI and WILLIAM J. HARRIS, JR.**

Excellent thermal conductivity and high specific heat are the most important properties of materials for heavy-wall heat sink applications. These properties enable rapid diffusion of heat generated at an aerodynamic surface into the interior of the material. (P11h, P12r; SGA-h)

HEAVY-WALL HEAT SINK SYSTEMS require materials with a high capability to transfer heat from the aerodynamic surface to the interior of the wall, or in other words, materials with high heat diffusivity. This property depends on thermal conductivity and specific heat of the material. None of the potential heat sink materials have high capacities in both, so the order of merit of the best materials is determined by a high value of one or the other property.

The heat flux, q-max, which may be applied to a heavy-wall heat sink depends on the heat diffusivity and within limits on the wall thickness. The melting point of the material is important only as it relates to aerodynamic heat protection by emittance from a hot surface. Of the potential heavy-wall heat sink materials, only beryllium oxide (BeO) and graphite have significant additional heat protection features involving the emittance factor.

Evaluation of Materials

The usual reference for the weight efficiency of absorptive systems, including the heat sink systems, is the effective heat capacity, Q, which is defined as the aerodynamic heat input in Btu. per. sq.ft., divided by the weight of the material required for thermal protection. For materials which do not attain high radiative surface temperatures, the Q value depends primarily on specific heat.

However, an exact evaluation of a material cannot be predicated on handbook values of specific heat. This is because the nature of the transient temperature gradients during pulse heating determines the extent to which the potential heat capacity of the subsurface material is utilized.

The mechanism of heat absorption by heat sink systems is illustrated in Fig. 1. Let us assume that the q-max heat flux value, denoted by point A, is the melting limit of a material as a radiative heat shield involving a wall of sheet metal thickness. From a thermal point of view, the radiative wall surface may be represented as having a negligible heat capacity. For higher values of q-max, the thickness of the skin must be increased to provide the heat capacity required to prevent melting. As the thickness is increased to match the requirements for higher aerodynamic heat input, a limit is reached (semi-infinite thermal thickness) beyond which increasing the thickness does not give further increase in q-max capability.

This limit is established by the capability of the material to transfer heat from the surface to the interior. The q-max value for melting of

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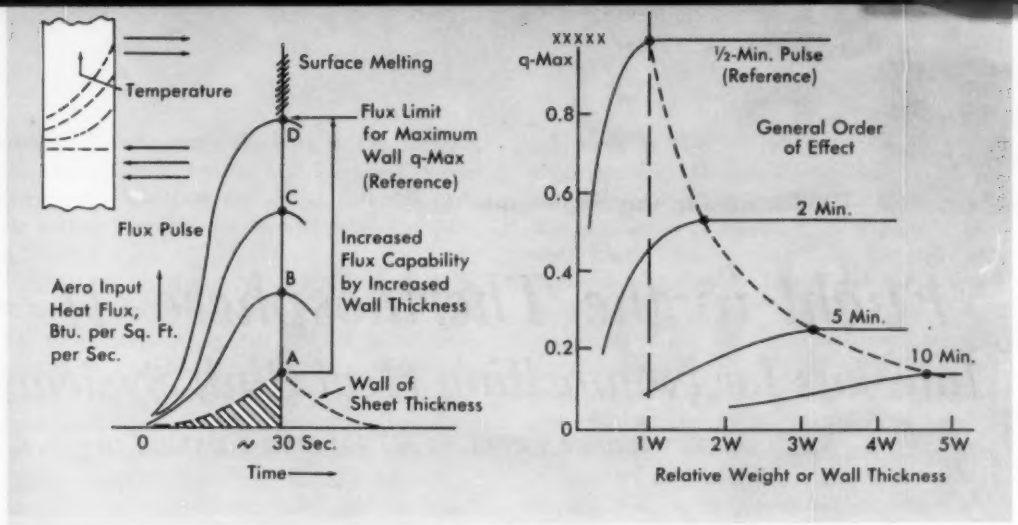


Fig. 1 — Illustrated Above Is the Mechanism of Heat Absorption by Heat Sink Systems. As the thickness of the wall is increased to provide for higher heat input, a limit is reached beyond which additional thickness is not effective. This is determined by the capability of the material to transfer heat from the surface to the interior

a material of semi-infinite thermal thickness is a characteristic of its heat diffusivity (considering q-max = q-max input − q-max radiated) and the shape of the heat pulse.

Exposure Time Is Important

For heat pulses of a similar bell-like shape, the important factor is the exposure time, t. The diagram on the right side of Fig. 1 illustrates the marked decrease in q-max capabilities and in the effective heat capacities which may be expected by extending the exposure time from t values of less than a minute to several minutes. This drastic decrease in efficiency of heavy-wall heat sink systems is due to the fact that increased time results in heating to deeper positions in the wall, with a consequent decrease in the temperature gradient from the surface. In other words, the steep temperature gradient required for high heat diffusion rates is replaced by a more gradual gradient which extends deeper into the wall. This requires an increase in wall thickness.

Usually heat sink performance of materials is thought of in terms of ballistic re-entry pulse conditions involving t values which are ordinarily less than 1 min. For purposes of this discussion, which is not intended to be limited to the ultra-short-time re-entry pulse conditions, we wish to avoid a rigorous categorization of material properties. The important considerations in a materials analysis are the relative positions of the principal contenders for heat sink applications.

Most Promising Materials

On the basis of heat diffusivity, the best materials are graphite, molybdenum, copper, beryllium and beryllium oxide. The relative virtues and problems of these materials for use as heat sinks are summarized in Table I. The high heat flux capacity and low Q value of copper result

Table I — Characteristics of Principal Heavy-Wall Heat Sink Materials

	Heat Sink Scale		Relative Weight as Heat Sink	Fabrication	Oxidation Resistance
	q-Max Capability (*a*)	Q^* Value Capability (*b*)			
Beryllium	High	High	Light	Extremely difficult (brittle)	Poor
Molybdenum	High	Low	Very heavy	Difficult	Poor
Copper	High	Very low	Very heavy	Easy	Good
Beryllium Oxide	High	High	Light	Extremely difficult (brittle)	Excellent
Graphite	Very high	Very high	Very light	Extremely difficult (brittle)	Poor

(*a*) q-max is peak value of aerodynamic heat flux in Btu.'s per sq.ft. per sec.
(*b*) Q^* is total aerodynamic heat input in Btu. per sq.ft. divided by weight of material required for the thermal protection function.

from its high thermal conductivity and low specific heat capacity. Beryllium, beryllium oxide, and graphite have very high specific heat capacities but low thermal conductivities at high temperatures, compared to high conductivity metals. Molybdenum offers moderate values in both respects.

Titanium and steels, which are not included in Table I, are not of primary interest because their relatively low conductivity is not offset by high specific heat properties. It is unfortunate that materials with the most desirable combinations of thermal properties are the most difficult to fabricate. Beryllium oxide and graphite, which provide for high heat flux capability and light-weight construction, are highly brittle and difficult to fabricate.

Graphite is resistant to heat shock but beryllium oxide is typical of ceramics in being sensitive to heat shock. Beryllium is a difficult metal to fabricate, requiring close temperature control for hot forging without fracture. It is brittle at normal temperatures and toxic in the form of airborne dust.

Molybdenum is least appealing because its relatively poor combinations of thermal properties result in very heavy weight for thermal protection. This is close to that of copper without benefit of copper's ease of fabrication. From an oxidation point of view, graphite is not suitable for heat sink applications in its present form, while beryllium and molybdenum would be acceptable, at least, for short-time applications.

The Direction of Future Work

Requirements for improved materials for heat sink applications include: *(a)* development of oxidation resistant graphites, *(b)* improvements in processing technology of beryllium and beryllium oxide, and *(c)* development of composite materials having enhanced thermal diffusivity compared with individual components.

The main factor in the last item is the increase in conductivity that can be achieved for the leading contenders without greatly decreasing the specific heat capacity. These properties are governed by the mixtures; that is, they are simply a function of the relative amounts of materials used for the mixture.

Ceramic coatings applied to heat sink metals may greatly reduce the maximum heat flux which the metal may withstand. This is due to the lower heat diffusivity of ceramic materials compared to that of heat sink metals. Detrimental effects then can be expected when ceramic coatings are applied to heat sink metals.

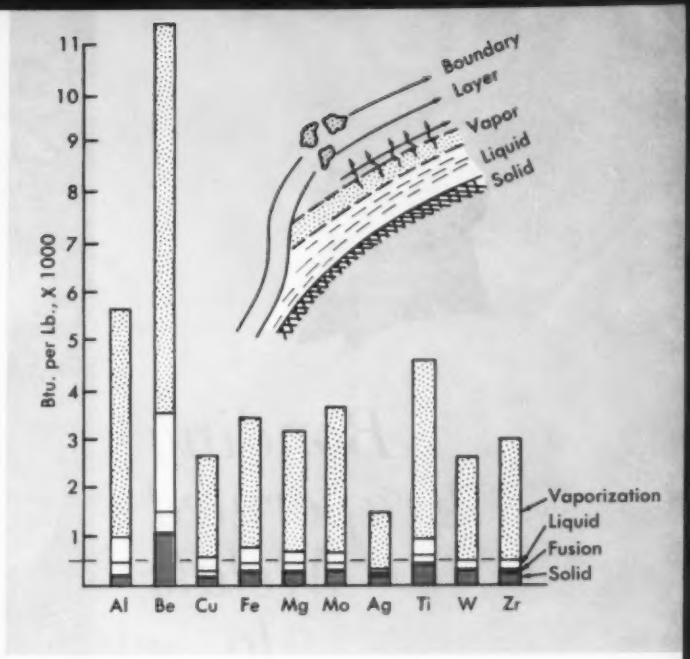


Fig. 2 – Comparison of Heat Capacities of Materials Due to Changes in State. Melting and vaporization of heat sink materials do not enhance their capabilities because, as illustrated in the sketch above, when the metal or ceramic begins to melt, the air stream will sweep away particles before the heat of vaporization is reached

The backside temperature of thick-wall heat sink systems depends greatly on exposure time. Again, as in the case of other systems, a mixed system approach must be adopted to protect temperature-sensitive substructure and payloads. For applications involving exposure of a few minutes, additional protection may be obtained by the use of insulation. Because of the high conductivity of heat sink materials, the use of increased wall thickness to maintain a low backside temperature for such periods of time would require a prohibitive weight.

Before leaving the heat sink systems, something should be said about why melting and vaporization of heat sink materials does not provide a means for enhancing their capabilities. Figure 2 presents heats of solid, fusion, liquid, and vaporization states for various metals as a basis of discussion. While heat capacities due to the changes of state are extremely appealing, the fact is they are not realizable for homogeneous materials at the flux levels of interest for heavy-wall heat sinks. As the metal or ceramic begins to melt, the air stream will sweep away the particles before the heat of fusion or vaporization is attained, as shown in the upper part of Fig. 2.

Bonding Evaporated Metals to Stainless Steel

*By A. S. HOLIK**

Prizewinner in 14th Annual A.S.M. Metallographic Exhibit, Chicago, November 1959.

THE STRENGTH OF THE BOND between a metal and an evaporated coating may depend rather critically on the surface condition of the base metal. For example, the strength may increase in proportion to the effective surface area. In other words, a rough surface will give a stronger bond than a smooth surface. As an example, observe the surface above. Produced on Type 347 stainless steel by a combination of thermal and vacuum etching, it proved to be suitable for use in such evaporations. Since these coatings adhere to the base metal on a microscopic scale, the electron microscope is often needed to resolve the fine detail of these surfaces.

Thermal and vacuum etching of the stainless steel specimen was accomplished in a simple manner. First, the specimen was chemically polished. Two heat treatments at 1000° C. (1830° F.) – first, in hydrogen, then, in a vacuum – followed. The accompanying electron micrograph illustrates the type of surface produced by this etching technique.

Replication Technique

When the surface was ready, a negative collodion replica was made by coating it with a film of 1% collodion in amyl acetate. After drying, the replicating film was stripped from the specimen and shadow cast with chromium at an angle of 25° to the surface. It was then examined and photographed at 15,000 ×.

*General Electric Research Laboratory, Schenectady, N.Y.

New Iron-Base High-Temperature Alloy?

*By G. K. MANNING**

Hot hardness curves for iron alloys containing 20% chromium with nickel, columbium, and carbon suggest excellent high-temperature strength and give a clue to the potential of these alloys in applications at elevated temperature. (Q29p, Q27a, 2-62; Fe-b, SGA-h)

AUTOMOTIVE MANUFACTURERS are studying the small gas turbine engine quite intensively as a possible revolutionary type of automotive power. Material cost will be an important factor in determining whether or not a gas turbine can compete with the conventional internal combustion engine. Thus, iron-base alloys are being re-examined in a number of laboratories. If an inexpensive high-temperature alloy is to be developed, it will probably contain iron as a major component. With this application in mind, a number of iron-base alloys containing 20% chromium with various amounts of carbon, columbium and nickel were melted and used for exploratory tests. Composition of two of the alloys investigated and some of the more familiar alloys with which they were compared is shown in Table I. Chromium was included in all the alloys to provide oxidation resistance.

Initially it was hoped that columbium carbide would prove a superior precipitation hardening compound with appreciable amounts of it being taken into solution at a temperature just below the solidus, then being precipitated at perhaps 1800 to 1900° F. However, it appears that very little solution of columbium carbide occurs below the melting temperature. Nevertheless, and regardless of the strengthening mechanism that is involved, several of the alloys exhibited phenomenal hot hardness for iron-base alloys. The hot hardness data for the

*Division Chief, Battelle Memorial Institute, Columbus, Ohio. Data presented were obtained during work on a research program sponsored by Kennecott Sales Corp.

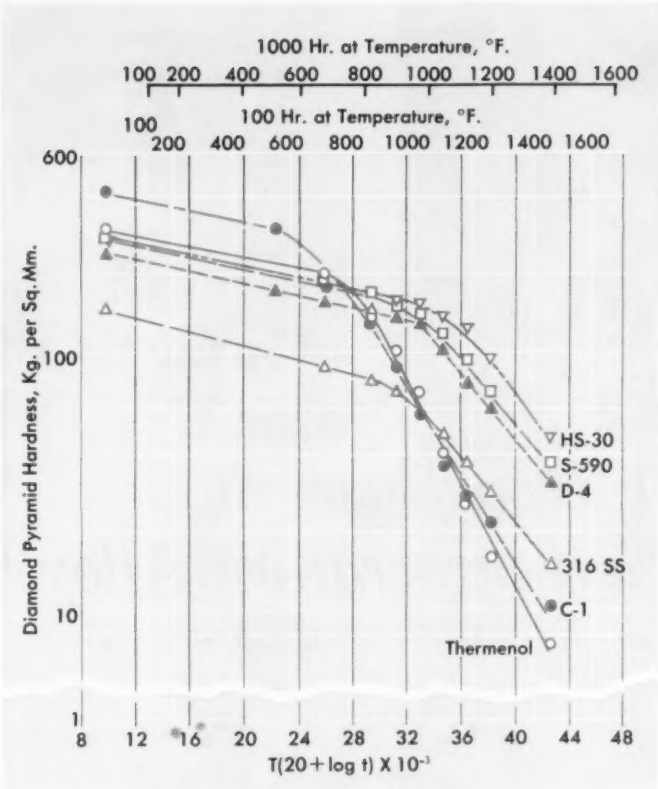


Fig. 1 – Hot Hardness of Two Experimental Iron-Base Alloys (C-1 and D-4) Compared With That of Some More-Familiar Alloys. T is temperature in degrees Rankine; t is exposure time in hours. Compositions are given in Table I

Table I – Composition of High-Temperature Alloys

Alloy	Carbon	Chromium	Nickel	Columbium	Molybdenum	Iron
HS-30 (*a*)	0.45%	26.0	14.4	—	62	1.5
S-590 (*b*)	0.42	20.5	20	4	4	24
Type 316	0.05	16.8	12.9	—	2.1	Bal.
Thermenol (*c*)	—	—	—	—	2 to 4	Bal.
D-4 (*d*)	0.81	20.9	13.7	2.48	—	Bal.
C-1 (*d*)	0.82	21.1	—	1.21	—	Bal.

(*a*) Balance cobalt.
(*b*) Also contains 20% Co, 4% W.
(*c*) Also contains 10 to 18% Al.
(*d*) Experimental alloys.

best austenitic (D-4) and the best ferritic alloy (C-1) are shown in Fig. 1. Hot hardness has correlated well with high temperature strength in previous studies and now this preliminary work suggests that "pay dirt" may be close by.

Hot Hardness Curves

The hot hardness curve for the austenitic alloy D-4 is of interest not only because it follows closely those of the cobalt-containing alloys, but also because it shows a "break" point of 33,000 on the Larson-Miller parameter. A number of recent articles, such as one by E. E. Underwood (*Materials and Methods*, April 1957, p. 127), have shown that, in the absence of allotropic changes, time and temperature can be related by the Larson-Miller parameter, which has the form $T(C + \log t)$, where T is absolute temperature in degrees Rankine, t is time in hours, and C is a constant that usually

has a value between 15 and 25. Other iron-base alloys have always exhibited "break points" considerably less than 33,000. Thus, at first thought, the high value obtained for D-4 alloy may be surprising. But there are no theoretical reasons why iron-base alloys cannot have so high a "break". One of the things that has puzzled metallurgists for years has been why iron-base alloys had less strength at high temperature than either cobalt or nickel-base alloys. The three elements occupy adjacent positions in the periodic table. Iron has the highest melting point of the three. The answer seems to be that more effective slip-preventing agents have been found for cobalt and nickel alloys than for iron alloys. But this does not mean that iron-base alloys are inherently weak at high temperature. Perhaps at long last we are on the verge of finding a more effective way of reducing slip in iron-base alloys.

Changes in Microstructure

Both C-1 and D-4 alloy exhibited greater hot hardness when given a high-temperature heat treatment than when tested in the hot rolled condition. The data in Fig. 1 for the two experimental alloys were obtained from samples heated for 2 hr. at 2300° F., water quenched, and reheated for 1 hr. at 1200° F. prior to testing. Figure 2 and 3 show the austenitic microstructures of the two alloys after treatment at 2300° F. As shown, both contain two distinct kinds of carbide presumed to be CbC and Cr_4C. Upon heating to 1200° F., the matrix of alloy C-1 changed to one which must be substantially ferritic as indicated by a large increase in magnetic permeability. The microstructure of alloy C-1 suggests that the decomposition occurred by means of a bainitic type of reaction while the alloy was at 1200° F. On the other hand, it appears that the matrix of alloy D-4 is stable austenite. Magnetic permeability of alloy D-4 remained low and constant after reheating at intervals of 100° to as high as 1900° F.

Future Work Planned

At the present time there are only a few facts known about the alloys. There are many more things that are unknown. Our experience has shown that the alloys can be forged and rolled without tearing or cracking. Some were even cold rolled without difficulty. Most of the carbide phase thought to be Cr_4C goes into solution upon heating to 2300° F.; however, very little of the phase thought to be CbC dissolves at that temperature. The hot hardness curves suggest excellent high-temperature strength, but no direct determinations of stress-rupture or creep strength have been made. There is no assurance that the composition studied represented the optimum composition. In fact, it would be remarkable if superior compositions did not exist. Similarly, there is no assurance that the heat treatment employed results in the best high-temperature strength. Nevertheless, the results are sufficiently promising to warrant more extensive study.

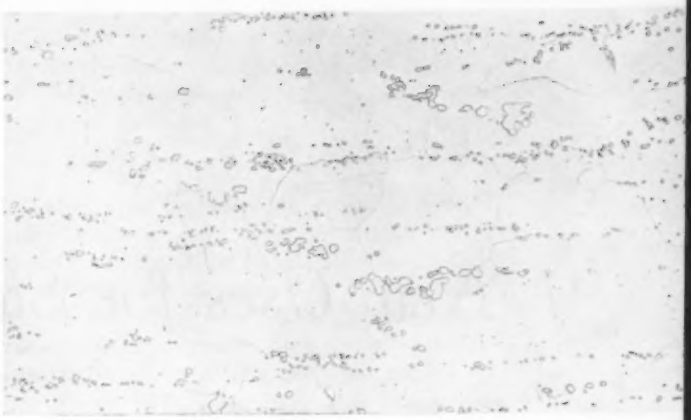


Fig. 2 – Microstructure of Alloy C-1 After Being Heated at 2300° F. for 2 Hr. and Water Quenched. Austenitic structure transforms to ferrite when alloy is reheated to 1200° F. Particles are columbium and chromium carbides. 500 ×

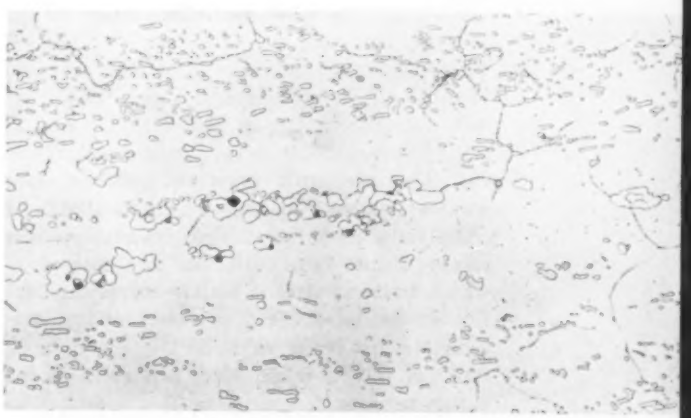


Fig. 3 – Alloy D-4 Water Quenched After 2 Hr. at 2300° F. Columbium and chromium carbides are present as in C-1 alloy but austenitic structure is stable to as high as 1900° F. 500 ×

New Uses for Stainless Steel

*By GEORGE C. KIEFER**

Stainless steel is making gains in new fields and extending existing markets. Fabricating techniques, new to stainless steel, are broadening its application in automotive, architectural, industrial and other areas. (T-general; SS, 17-57)

BOTTLES, CHIMNEYS AND CHIMNEY LINERS, window frames, sinks, awnings, mailboxes, a completely new all stainless-steel truck, and a refuse disintegrator — all are applications in which stainless steel is finding increasing use. For automobiles, stainless steel mufflers and bumpers are being studied. The selection of stainless for these products has come about within the past few months.

Last year, for the first time a complete main steam condenser was retubed completely with stainless steel. This was done at the Monongahela Power Co.'s station in Rivesville, W. Va. The condenser requires over 9000 stainless steel tubes, 26 ft. long and ⅞ in. O.D., which give a condensing surface area of 55,000 sq. ft. About 45,000 gal. of water per min. from the Monongahela River is pumped through the condenser. The water at Rivesville is acidic (pH sometimes as low as 2.8). With stainless steel, tubes having thinner walls are permissible, greater water velocity can be handled, and better performance with less cleaning maintenance is expected.

The new stainless steel bottle shown in Fig. 1 atomizes and dispenses medicine at the flick of the thumb. The bottle is believed to be one on the first to dispense internal medication by the aerosol process. It is made of Type 305 stainless steel and is 13/16 in. in diameter and 2½ in. long. The bottle starts as a 3-in. square blank of steel, 0.010 in. thick, and is formed in six draws on a transfer press. The work is done on an 11-stage press, which curls the edges and prepares the bottle for the cap. One of the most unusual bottle parts is the valve stem, also Type 305. The stem is made on a ten-station press from a blank 39/64 in. in diameter. In six draws it is grooved, set formed, and trimmed. All this is done without heat treating or intermediate annealing.

A newly designed refuse disintegrator, now made of stainless steel, is helping restaurants, hotels, food stores, industry, hospitals, schools and camps to save money and space. The new disintegrator can reduce 300 lb. of garbage, paper or other refuse per hr. to an odorless, insect and rodent-proof mass. Refuse is reduced in volume by 80% and the end product makes an excellent organic soil conditioner. Designed originally with a carbon steel exterior, the disintegrator soon proved to be a

*Manager, Application Development Dept., Allegheny Ludlum Steel Corp., Pittsburgh.

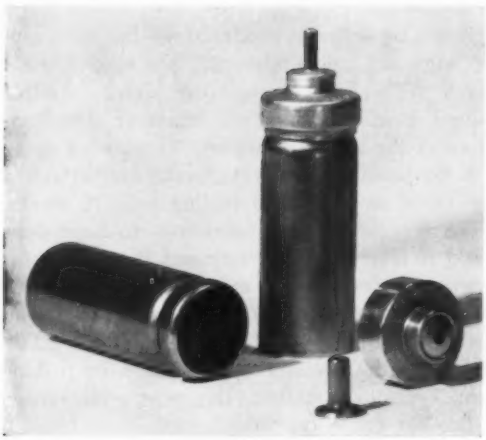


Fig. 1 – New Aerosol Bottle Made of Type 305 Stainless Is Designed to Dispense Internal Medication. Bottle is formed from a 3-in. square blank in six draws on an 11-stage transfer press without intermediate anneals

maintenance problem, solved only by switching to stainless steel.

In the architectural field, stainless steel window frames are becoming more popular. Press brake forming, the usual method for making frame components, is giving way to roll forming. As a result, costs are dropping and stainless frames are becoming more competitive with other metal windows.

Home Market Grows

In 1958 about 13% of sink bowls produced were of stainless steel. Fabricators predict, however, that by 1964 this figure will grow to about 40 to 50% and by 1969 to more than 75%.

Today, sink bowls are fabricated differently than they were a few years ago. They were formerly made by cutting the pieces out, welding them together, then grinding to proper contours. Now most sink bowls are drawn. Production costs are lower, productivity is higher.

A new line of stainless steel mailboxes (Fig. 2), designed with corrosion resistance and long-time attractiveness in mind, is being made by the Village Blacksmith Div., General Metals Corp., Watertown, Wis. Seven pounds of Type 430 stainless steel was used in the first mailbox, which measures 15¾ in. long, 7¼ in. high and 4½ in. deep.

One of the unique applications in the home building field is a stainless steel chimney and liner. The chimney is composed of two stainless steel pipes – an outer pipe 14 in. in diameter and an inner pipe 12 in. in diameter. A 1-in. layer of insulation surrounds the inner pipe. The chimney, made by forming and then welding the pipe lengthwise, is buffed to give it a satin finish.

New Uses in Autos, Trucks

Because of the corrosive problem, several dairy companies have switched to truck bodies made entirely of Type 302 stainless steel. One of the first models, designed by Schnabel Co., Pittsburgh, uses about 3000 lb. of the metal. All seams are welded, then buffed. Truck capacity is about 1800 gal. of ice cream.

Stainless steel mufflers have been field tested throughout the nation and are now available. None of the stainless steels (Types 430, 304 and 310) have shown evidence of corrosion after severe tests.

Field tests are now being conducted on automobile bumpers clad on both sides with Type 301 stainless. After two years of testing there is no pitting, peeling or corrosion. In addition, bumpers clad with stainless steel have been employed for the first time on 60 buses made by Mack Trucks, Inc., of Allentown, Pa. The clad bumper stock was of 0.118 gage, 17¼ in. wide by 108⅝ in. long. The Parish Pressed Steel Div. of Dana Corp. in Reading, Pa., forms the bumper in a single stroke on a 132-in., 1000-

Fig. 2 – Stainless Steel Mailboxes Like That Shown Have Been Introduced by Village Blacksmith Div., General Metals Corp., Watertown, Wis. Although expensive ($15 to $50), they will last a long time

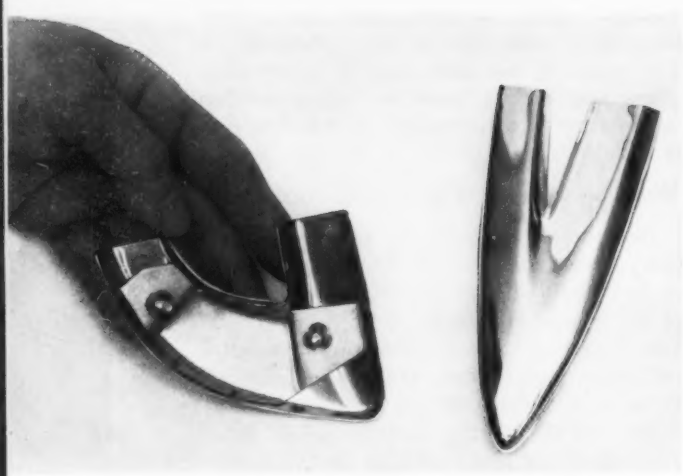


Fig. 3 – Low-Voltage, High-Current Welding Method, Developed by Primeweld Corp., Dearborn, Mich., Can Attach Stainless Steel Auto Trim to Mounting Brackets Without Marring Bright Surface

lb. capacity press. The bumper weighs 66 lb. when finished. Trimming is not necessary.

Rapid Joining Method

A comparatively new method of fastening stainless steel molding and appliqués (Fig. 3) to automobiles has been developed by the Primeweld Corp., Dearborn, Mich. Primeweld engineers report good results in welding with low voltage and high amperage. The welder sends enough "wallop" through the pieces to effect quick joining without distortion or discoloration of the metal. Formerly 11 separate operations were necessary to make and attach a piece of molding, and tooling took 12 weeks. The new method cuts fabrication to three steps and reduces the time required to tool up for production. Die costs are also reduced. Maximum thickness which can be welded by Primeweld's method is 0.090 in.; minimum is 0.022 in. Most of the preliminary work has been done on Type 430 stainless, the most widely used stainless grade on today's cars.

Gives Frosted Surface

A new finish called "Fro-Zon" has been developed by Stamping Service, Inc., Detroit. The process forms tiny mounds on the surface of the metal which diffuse light rays and makes the metal surface appear frosted (Fig. 4). All kinds of patterns, lettering, bossed, deposed, flat or contoured surface can be finished with Fro-Zon. Work has been limited to automotive applications, but the developers are aiming at the home appliance and cooking utensils, architectural, furniture, toy and related fields. The finish, which is applied after the part has been formed, can be put on any size, shape, type or gage of stainless.

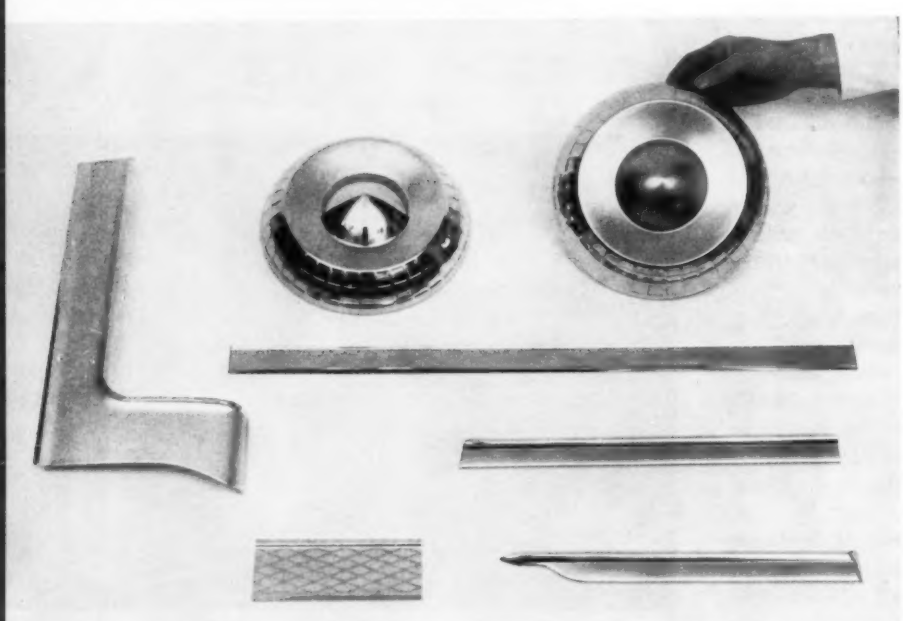


Fig. 4 – New Finish Gives Stainless Steel a Soft, Frosted Look

Power From Gas-Cooled Reactors

*By E. E. THUM**

In England much power is generated in reactors using natural uranium as fuel. American engineers believe that operating temperatures should be much higher, and so prefer enriched uranium oxide as fuel and use stainless steel or graphite for heat resistant containers. (W 11 p)

ANYONE WHO HAS GIVEN MUCH ATTENTION to the possibilities of generating power from the atom knows that there are many ways of constructing a nuclear reactor or furnace. The heat source may be any radioactive element (as yet it is limited to uranium or plutonium and usually to natural uranium or uranium enriched to various percentages of the more active isotope U^{235}). Uranium can be used as metal or as a compound such as oxide or carbide. It can be in bars, rods, lumps, fine dispersions or in solution. It can be "moderated" in various degrees – that is, the fast electrons slowed down appropriately – by several substances such as graphite, beryllia, ordinary or heavy water, or a heat resistant hydrocarbon. The reactor can be designed so that vagrant neutrons are absorbed by a thorium shield and thereby create more radioactive material. The heat can be taken directly to an engine or turbine by the "coolant" or heat transfer medium, or an exchanger can be interposed between reactor and turbine. In short, the permutations and combinations are almost endless, and even a Univac could not choose the best combination or "optimize the design", to use a common cliché.

To state this situation is to give the reason why there are so many developmental projects under way in the field of atomic energy. They range all the way from a prospectus, through a feasibility study, to experimental work on difficult details, to pilot plants, prototypes and full-scale power producers. In the latter category we have, of course, two important examples – first, the gas-cooled, low-temperature reactor getting heat from a chain reaction in natural uranium, and feeding electrical power into the national grid in England, and second, the water cooled, high-pressure reactor using enriched uranium installed in American submarines. Each design has proved its worth, although their reasons for being are quite different. For example, the large nuclear power plants in Great Britain are (hopefully) to compete with others whose fuel is coal or petroleum; low-cost power is a major objective (plus by-product plutonium). On the other hand, the compact submarine power plant can operate without oxygen and gives the vessel completely new capabilities in speed, endurance and operations; cost per kw. is not a ruling factor.

It should be said that a decade of intensive work has chilled some of the enthusiastic predictions that the coal-fired central station is on its way out. In favored America, where such power may be made in our industrial areas for no more than 7 mills per kw-hr., the competitive chances are so slim that the various regional combinations of utility companies who are now building reactors can justify the projects only on the basis that ways to cut costs cannot be found except by working with an operating installation. An example is in England, where the cost of atomic power generated during the last eight years is steadily dropping and the new "generation" of power plants to go on line in 1963 will make electricity at only 20% more than that from the most modern coal-fired plants, even considering the fact that improved design of the latter has simultaneously cut the unit cost by 10%. It is therefore

*Editor-in-Chief, *Metal Progress*.

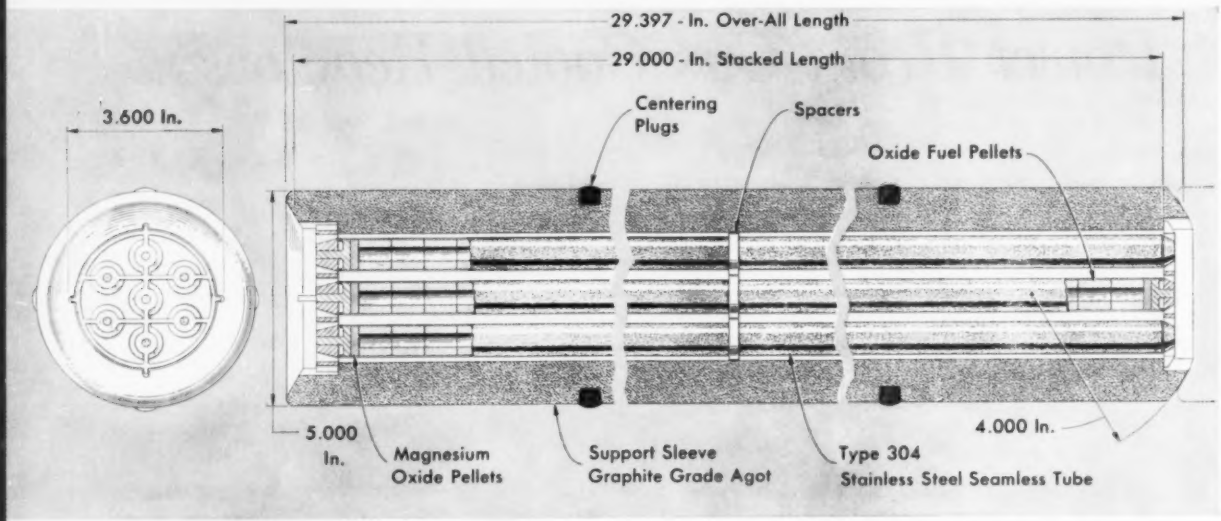


Fig. 1 — Fuel Assembly for the Experimental Gas-Cooled Reactor (EGCR) To Be Built at Oak Ridge National Laboratory

not surprising that existing and authorized programs in England, France and Italy contemplate the steady generation of 3 million electrical kilowatts by reactor plants of this type. Compared with this, the program in America could truly be called "experimental". (One explanation of the unfavorable situation in the United States is that capital costs over here are half again as much as in England, so that our plants cost $30 to $50 per kw. of capacity more than in the U.K.)

Experience in Great Britain

Steady technological advance in the plants of the United Kingdom Atomic Energy Authority was described by several speakers at a recent symposium on gas-cooled reactors held by the American Nuclear Society, with Franklin Institute in Philadelphia acting as host. The first reactors started at Calder Hall in 1956.* The fuel is the cheapest — natural uranium slugs — canned in magnesium alloy sheet called "Magnox". The moderator is graphite. The coolant is CO_2, coming out at about 550° F.

The second generation of reactors increased the thermal efficiency of the plant in the most obvious way, namely by increasing the operating temperature. The natural uranium fuel is canned in aluminum. The design is still very simple, the least expensive, in effect a block of graphite pierced with round holes each containing a string of fuel elements.

The third generation, to start up in 1963, is designed for operation at still higher exit temperature, 1000° F. Each plant will produce 100,000 kw. of heat and turn out 27,000 kw. of electricity. The fuel elements (made in a modern production line by mass production methods) are clusters of thin pencils. To avoid troubles from large dimensional changes in uranium metal at its allotropic transformations (1240 and 1420° F.) the fissile material is an oxide of enriched uranium. Oxide powder and stainless steel powder are compacted into pellets and placed in a long, tight stainless steel can and a cluster of these is placed in a graphite sleeve (the moderator). Sir William Cook, head of the Authority, said that when the graphite moderator can be replaced with beryllia, the neutron economy will be so improved, the needed enrichment and fuel cost minimized, and the capital charges reduced so that such a plant would be competitive with the best coal station.† The British seem to have gone on the principle that you can get as far or even further by perfecting an old project as you can by

*See "Metallurgical Aspects of Calder Hall", by Tom Bishop, *Metal Progress*, June 1957, p. 65.

†Interest in beryllia as a moderator is also increasing in America. The fuel rods for the maritime gas-cooled reactor are a compact of UO_2 diluted with Al_2O_3 and BeO_2 contained in stainless steel tubes — only two thirds as large and two thirds as heavy as the equivalent in a pressurized water reactor. Since the cost of beryllia is about one third what it used to be, it becomes attractive as a moderator despite the toxic effect of air-borne particles.

putting the same amount of money and effort into a new one.

Along this line, Sir William described a research reactor now under design for even higher outlet temperature, 1300° F. Enriched oxide sleeves would be placed in the annular space between two graphite tubes. Three gaseous coolants will be studied, namely, CO_2, N and He. Yet to be proved is the assumption that graphite tubing can be made dense enough to contain the fission products (especially the gases krypton and xenon), that it will not change size and shape during long radiation, and that CO_2 will not attack it and carry much soot out into the cooler parts of the system.

American Desigus

These are the worries, also, which haunt the many Americans who have only belatedly turned their attention to gas cooling. Owing to the availability of U^{235}, and true to our predilection to go to extremes, Americans usually are thinking of a very hot reactor (at least 1500° F. at exit) – so hot that the fissile material cannot be in the metallic state. A compact of graphite powder mixed with oxide or carbide of enriched uranium is preferred; sometimes thorium for breeding is in the same mixture. Short thimbles of these are to be stacked in the annular space between graphite tubes and as many as seven are bundled into a single unit in hexagonal array. In one proposal the outer graphite tubes are double, fission gases are intended to diffuse through the slightly porous inner sleeve and be stopped by the outer tube and drained away without getting into and contaminating the main coolant stream outside. Not all the elements proposed are as complex as these, by any means. The 40,000-kw. plant now being built for Philadelphia Electric Co. will have enriched uranium compacts nested in a rugged graphite tube 3½ in. outside diameter. Such an element will operate at 3000° F. at the center and 2000° F. at the surface; heat transfer is largely by radiation so intimate contact between fissile material and the container is not so paramount a necessity. This combination of high operating temperature, high power density, high burn-up of fissile material, and good neutron economy (there being much graphite and little metal in the reactor itself) leads the designers – General Dynamics Corp. – to predict that this plant will appproach closely if not reach the goal of 7-mill power.

Pebble Beds

Another very appealing idea (intently studied by the engineering firm of Sanderson and Porter and planned for a 50,000-kw. reactor to be built near Munich by Brown-Boveri and Krupp) is that the compacts should be round marbles or pebbles, loosely contained in the reactor shell; about a thousand new ones would be poured in and the old ones drained off daily to keep the radio-activity of the pebble bed at a constant. In a random arrangement of uniform spheres there is about 40% voids for passage of coolant gas, and the temperature can go to 1800° F. at the surface without any tendency for the pebbles to fuse together. A reactor to generate heat for a 150,000-kw. electrical station would require 290,000 pebbles containing thorium in the blanket and 230,000 containing uranium in the core.

This very simple concept turns out to be not as simple as it looks. The pebbles can be machined from a graphite block and then soaked in a solution of enriched uranium nitrate. (In operation the nitrate is converted into a finely disseminated dispersion of uranium carbide.) Or a proper mixture of powdered oxides and graphite can be formed into balls by powder metallurgical methods. Unfortunately, in operation the uranium and its fission products tend to diffuse from the hot center to the cooler surface of the sphere and thence to enter and contaminate the stream of coolant. This can be prevented, in large measure, by coating the ball with a 5-mil layer of "siliconized silicon carbide", or by a dense "pyrolytic" or "pyrographic" carbon. These should resist 300 psi. internal pressure of krypton and xenon. An even more striking scheme has just been devised at Battelle Memorial Institute for coating each tiny particle of uranium oxide with an impervious layer of alumina.

In the so-called "turret experiment" at Los Alamos this high contamination of the helium circuit will be endured but the gas will be continuously cleaned by circulating it through appropriate absorption towers. The reactor elements are 1-in. rods of graphite, 6 ft. long, pierced axially with a half-inch hole. They are first soaked in uranium nitrate. They are unclad – operate bare up to 3000° F. The outlet temperature is to be 2400° F. and the hot helium gas is cooled in a heat exchanger. There are only two moving pieces of machinery in the plant; these are a completely enclosed blower

and a regulator for the clean-up bypass.

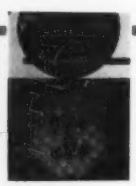
Americans tend to discount CO_2 as a coolant proposing instead an inert gas. Nitrogen is the cheapest, and is actually to be used in the package reactor now being designed for the Army by Aerojet-General Nucleonics. It, however, has an effluent at 300 psi. and 1200° F., and even under such relatively mild conditions the gas rapidly nitrides and embrittles the inner surfaces of the metal containment system unless the nitrogen contains a tiny amount of oxygen.

When cooling gas leaves the reactor at even higher temperatures – say, at least 1500° F. – helium seems to be the best coolant. It ought to be inert, but even helium must be kept scrupulously clean. Particularly true is this of its hydrogen and oxygen content, entering as traces of moisture in the make-up gas, from blower lubricant, or sucked out of the structure itself. A few parts per million of hydrogen seems to activate the transport of carbon (via CO gas) from a hot graphite fuel element to cooler piping system outside the reactor, where soot deposits rapidly, especially if the temperature fluctuates slightly. This carburizes steel. Even nickel and other refractory metals which do not carburize in the true sense are damaged by a little-understood reaction wherein carbon nodules grow at the grain boundaries and actually pry off tiny metallic fragments from the surfaces. Monel metal seems to be immune to this damage, and the search is on for platings which will prevent such carbon penetration.

Of course, not all American proposals are for all-ceramic systems, and since *Metal Progress* is a metallurgical journal, it may be well to end on a metallurgical note – namely, that carbon has not entirely replaced metal as a shielding or canning material in these advanced designs. For example, a helium-cooled reactor is under construction at Oak Ridge. While its primary purpose is to determine the relative advantages of numerous "loops", each capable of generating power, it is otherwise a prototype of a full-scale power producer. The uranium oxide fuel pellets (enriched) are contained in Type 304 stainless steel tubes 0.75 in. diameter with 0.020-in. walls. Seven of these are nested and placed down the central hole in a graphite block. As already noted, one thing which will be discovered is how much these graphite moderators creep, shrink or otherwise deform during continuous operation above 1050° F. Another unpredictable item that will be determined is the maximum internal gas pressure in a tight "can" due to the fission products krypton and xenon.

Another project calls for a *really* complicated fuel element. Aerojet-General Nucleonics has designed a system for a proposed Army reactor wherein each long, thin (1¾-in. diameter) tube is a complicated assembly. The outer sheath is zirconium and it is separated from an inner stainless steel liner by a thin wall of insulation. Inside this stainless tube are four concentric "pipes", separated by knobby spacers, each pipe made of stainless sheet containing a dispersion of enriched UO_2. The gas coolant flows up this tube in the annular gaps between them and through the center. Heavy water is outside the zirconium sheath.

That's as complicated as you can get!



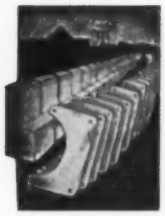
On the Cover—Inside the Package Power Reactor.

The striking photograph on the front cover of this month's issue of *Metal Progress* depicts the core in the Army's SM-1 (Stationary Medium Power Reactor), illuminated by bluish light, a characteristic of Cerenkov radiation. Located at Fort Belvoir, Va., the SM-1 was formerly known as the package power reactor (APPR-1). The photograph was taken at a power level of 50 kw. with all of the seven contact rods partially withdrawn, according to Col. John A. Hughes, Jr., who represents the A.E.C. at Fort Belvoir, which operates the reactor.

Since going into operation on April 15, 1957, SM-1 has produced about 25,000,000 net electrical kw-hr. of energy from 20 lb. of nuclear fuel – enough to supply a typical community of 8000 with electrical power for a year. Alco Products, Inc., which built the nuclear power plant, states that it is the first demonstration of the practicability of nuclear plants for package-type, remote site power generation.

During the three years since going on line, SM-1 has been a valuable research and development tool. The plant has trained the men who will operate SM-1's descendants – SM-1A, SM-2, PM-1 and PM-2A. In the test and training program, the reactor has been subjected to far greater rigors than any other nuclear or conventional plant used for power generation. For example, the plant has been brought to full power and back to shutdown in a short time, often several times per 8-hr. shift. Such rapid cycling means severe thermal and mechanical shock to components in the system.

After its first refueling, scheduled for the first half of this year, SM-1 will continue to serve in the search for nuclear plants of the future – both military and civilian. A.G.G.



Short Runs

Levitation— New Tool for Metallurgy

METALS CAN NOW BE MELTED completely free of physical contact with any kind of crucible; electromagnetic forces, created by a special high-frequency coil, hold them suspended while they are melted. This coil is the heart of the "levitation" furnace developed by Westinghouse Electric Corp. and built by NRC Equipment Corp.

Intended for laboratory use, this new type of furnace (see Fig. 1) can produce large numbers of small castings for physical property studies. It is also helpful in developing new alloy systems.

How the Equipment Operates

Two primary pieces comprise the apparatus – a 10-kw., 450-kc., R-F generator, and a chamber in which melting can be performed in an inert atmosphere or a vacuum. The chamber contains a conical coil which is connected to the generator leads. The lower turns of this coil are formed in one direction while the top consists of several counterturns. Thus, the current in the lower turns produces an electromagnetic field that is opposed by the field in the upper turns. This results in a weak field in the center of the coil. When a conducting material (usually a metal) is placed in the center, it is pushed toward the weak field, and floats in space. In short, the basic principle of levitation is that electromagnetic forces exerted on a conductor act to force it toward the zone where the field is weakest.

As stated before, when a charge is placed inside the coil and the power is turned on, the charge floats in space. While it floats, the induced currents heat it to the melting temperature and vigorously stir the liquid metal. When this power is reduced, the melt funnels through the bottom of the coil into a water cooled mold. Since the melt never touches the coil, is melted in an inert gas or vacuum, and freezes as it strikes the mold, the metal cannot be contaminated. Thus, small castings of extreme purity are produced. In addition, there is no macrosegregation – provided, of course, that the material is floated for a sufficient period of time to insure good homogeneity. For example, in the chromium-nickel stainless steels, 4 sec. is not enough, but 8 sec. is satisfactory.

Equipment in the chamber also includes a shelf on which the charge compacts are loaded, a manipulator for moving them into the coil, a water cooled copper table on which as many as 18 solid copper molds may be placed, and a stem for supporting and rotating the table.

The charges, which weigh from 4 to 28 g., may measure up to ⅝ in. in diameter and something less than that in height. Size depends upon whether the melting is done under an inert gas or a vacuum, and on the type of metal being melted. Of course, the size of the button or casting desired is also a factor.

Melts of 28 g. have been achieved with stainless steel, though 20 g. is considered a standard. In other instances, it is impossible to achieve stable levitation with charges this large. For other metals, average weights of about 10 g. are common.

These size limitations appear to be basic to the levitation process. True, it is possible to design coils which will support much larger compacts. However, once these compacts melt, there is trouble. That is because the induced currents, and their resulting fields, are largely on the surface, and are much stronger in the middle than at the bottom. As a result, there is little force other than surface tension to keep the metal in the middle of the melt from running out the bottom. So far, a way of increasing surface tension hasn't been found.

There are other serious limitations, one of which is the uncertainty of the process when new alloys are melted. The size of the charge

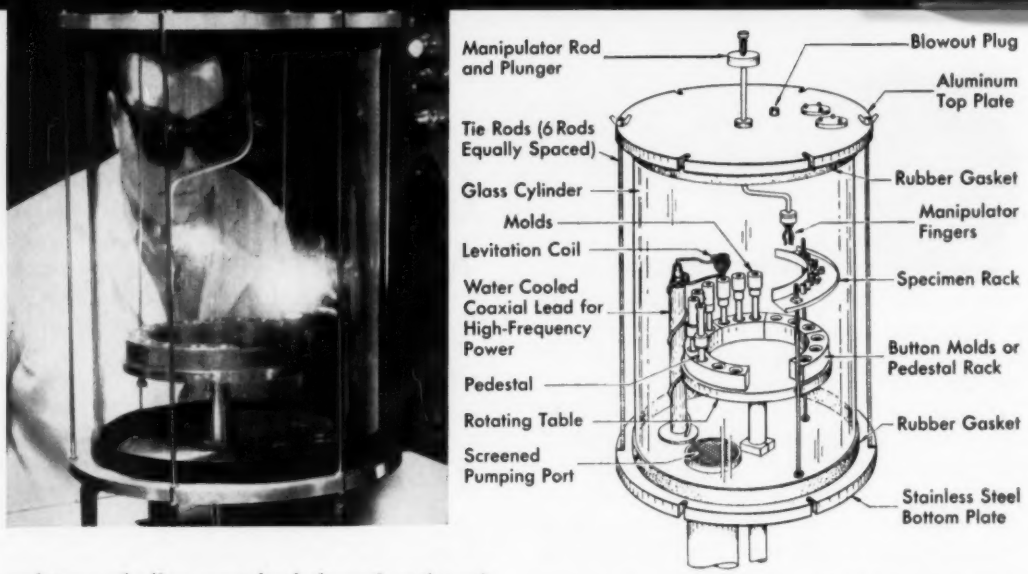


Fig. 1 – Levitation Furnace for Melting and Alloying Metals When Freedom From Contamination Is Required. Inset shows schematic diagram of the equipment. In the commercial model, the counterturns of the coil may be replaced by a metal stool which is placed above the conical R-F coil to create a counteracting field and float the melt in space

and type of alloy must be balanced with coil design, and this is, by and large, a problem which has only an empirical solution. Fortunately, small coils of this type are relatively easy and inexpensive to make.

In general, iron-base alloys are readily levitated and melted, and Westinghouse has made some 4000 different melts of various iron-base metals. Aluminum, copper, nickel and its alloys, titanium and zirconium and a number of their alloys, columbium, and tantalum are readily handled.

Insofar as other materials are concerned, more experience is needed. Many – including ruthenium, hafnium, vanadium, molybdenum and chromium, to name just a few – can be melted; on the other hand, some, such as tungsten, so far have resisted stubbornly. Tungsten floats nicely in the coil, but won't melt. Since only about 3200° C. (5800° F.) is reached, a supplementary heating source such as an electron beam will probably be needed if tungsten is to be melted.

Finally, there are occasional problems associated with operation. For instance, a charge may sometimes sway in space, touch a coil and create an arc. Even if it merely sways, a very steady hand is needed to turn off the current at the right moment so that the charge falls straight through the coil without touching it. Arcing also may be caused by impurities in the metal or by materials that vaporize in the lower temperature ranges. Thus, for all practical purposes, size and uncertainty of the equipment limit it to laboratory applications.

Advantages Are Unique

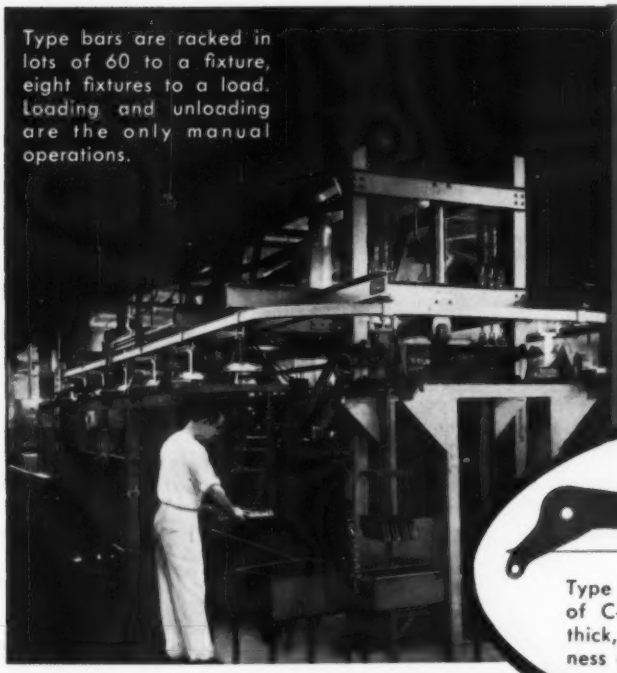
Levitation melting has some very distinct advantages, two of which – purification and homogeneity – have already been mentioned. For example, it is possible to take a charge of columbium with a Vickers hardness of over 160, float it molten in a vacuum for 15 to 20 sec. and come out with a specimen whose Vickers hardness is less than 60. Results with tantalum are equally impressive.

In addition, shaped parts, free from contamination, can be cast quite readily. Slabs, pins, buttons and sometimes simple shapes such as tensile specimens are produced by simply directing the metal into a shaped mold.

Perhaps its biggest appeal is the speed and ease – barring "surprises" – with which it turns out melts. Since the furnace can produce well over 100 samples per shift, the researcher is able to vary many more parameters in an experiment than would be practical with conventional furnaces.

To date, the principal applications of levitation melting have been to produce ultra-high-purity metals for some of the more exotic research needs, to produce small castings for corrosion investigation, to study new alloy systems such as those of titanium, to check the transformation points of various metals, and to study the hot cracking tendencies of metals.

Thus, levitation has finally reached the practical stage. It is difficult to predict its long-range future, but there is no question that it provides a versatile, high output laboratory tool which will be more widely employed as research continues on refractory and reactive metals.



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Circle 1311 on Page 48-A

CORRESPONDENCE

Error Noted

LAGUNA BEACH, CALIF.

In my note discussing the adoption of the Metric system, appearing on p. 134 of the January 1960 issue, an error was made in the 14th line of the second paragraph. The word "gradient" was incorrectly substituted for "quadrant" in the discussion of the quadrant of the meridian of longitude through Paris. There is no such thing as the gradient of a meridian – but there is certainly a quadrant of one!

ROLAND V. HUTCHINSON
Retired

We Weren't First

MADISON, WIS.

I'd like to correct a possible misinterpretation of a statement in my "Short Tour of Archeological Metallurgy" (December 1959, p. 94). On p. 95, the second sentence of the second paragraph, the first column, relates to the occurrence of native silver in intimate association with native copper. The inference from this paragraph is that we were the first to see it or recognize it. Nothing could be farther from the truth. The mineralogists have known it for generations, and it was the subject of much interest and speculation to Prof. H. C. H. Carpenter in one of his famous extracurricular metallurgical papers on the structure of native metals. In the article the erroneous impression is conveyed that we were the first ones to recognize this intimate association of silver with native copper. We weren't, of course, and knew it.

DAVID J. MACK
Professor of
Metallurgical Engineering
University of Wisconsin

A Bargain in Beryllium

WASHINGTON, D. C.

Here's an advertisement (see below) from a recent issue of a Washington newspaper which might interest some of your readers. It looks like a good opportunity to put those Confederate dollars to work.

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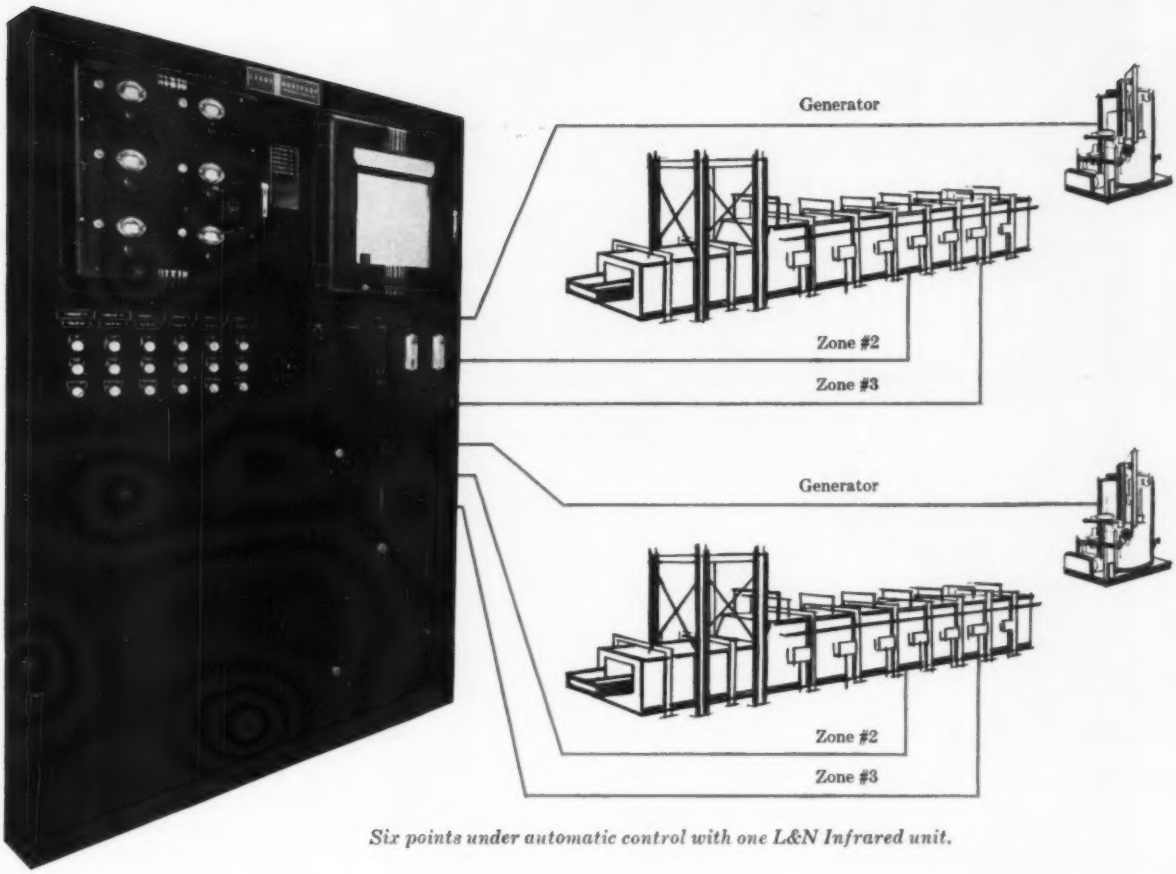
Beauty in Metallography

PHILADELPHIA

It seems to me that the marvelous photographs exhibited year by year at the A.S.M. Metallographic Exhibits might really be promoted as Exhibits of Modern Art! Modern artists have attempted to break away from tradition by offering new effects in form, line and color to attract the eye and intrigue the mind.

Opinion varies as to whether some of these represent beauty, even though requiring a special understanding, or whether (being deformations of nature) they are in fact monstrosities. Without attempting to give a precise definition of the word beauty, I submit that man's efforts to portray beauty may be judged by comparing it with the works of God as we view them in the amazing world around us. My belief is that the truest and greatest beauty is always found in Nature, the creation of the Supreme Artist. Nature is beautiful; distortion of nature, ugly.

The pictures on display at the A.S.M. Metallographic Exhibit – worthy of any I have seen in any art museum – represent structures in metals resulting from natural processes. Some are very highly magnified, even thousands of diameters. They were produced for their scientific or technical importance, usually with little or no thought of artistic creation. There is no handwork, no



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Circle 1313 on Page 48-A

Correspondence . . .

retouching, the colors are natural.

However, these reproductions of natural phenomena in the field of metals seem to embody the finest principles of what has been called "abstract art". They could readily be titled "Terraced Lands", "Suspension Bridge", "Dark Thoughts", "Nude Climbing a Ladder". Each viewer can word his own impression. The exhibits are worthy of thoughtful consideration of art lovers, students and critics as a subject for comparison with the works of some of our foremost celebrities in the fields of painting, sculpture and architecture.

HORACE C. KNERR
President
Metlab Co.

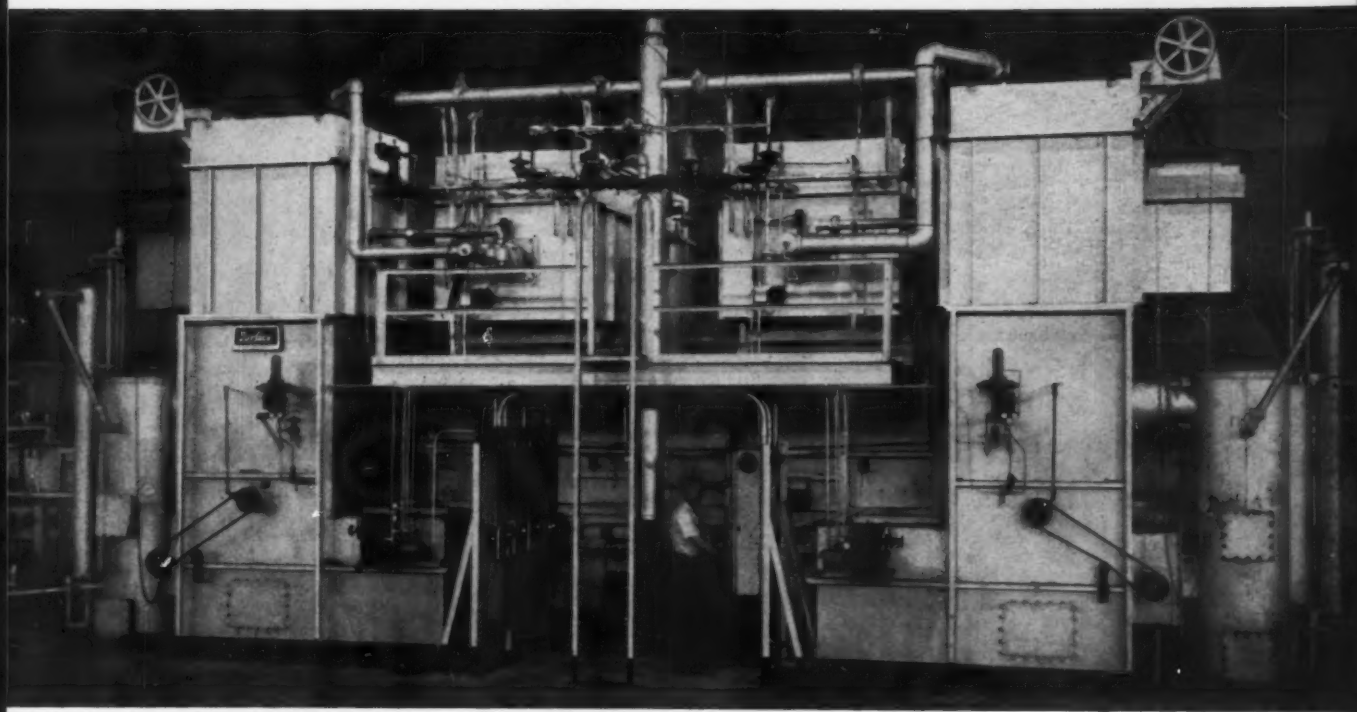
Austolize or Austulize

PITTSBURGH

The term "austenitizing temperature", which has been widely used during the past 20 years to designate the temperature to which steel is heated to form austenite and from which it is subsequently cooled at a controlled rate to form desired transformation products, is much more effective for indicating the treatment than the older terms "hardening temperature" and "annealing temperature", but it is still not altogether satisfactory. In most steels, particularly those containing more than about 0.25% carbon and medium to high in alloy content, the purpose of heating above the A_1 temperature is not only to form austenite but to get some or all of the carbides to dissolve in the newly formed austenite. The treatment is therefore a combination of austenitizing and solubilizing.

It seems to me that the term designating a heat treatment should be as specific as possible and therefore I suggest that a word be coined to specify heating both to form austenite and to dissolve carbides. My candidates for this portmanteau word are "austolize" and "austulize" (with long u, as in university). I would be very happy to have comments from your readers.

P. PAYSON
Assistant Director of Research
Crucible Steel Co. of America



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Circle 1296 on Page 48-A

PERSONAL MENTION

J. Herbert Hollomon

Walter R. Hibbard, Jr.

Ralph L. Wilson

J. HERBERT HOLLOMON has been named general manager of the General Engineering Laboratory of the General Electric Co. in Schenectady, N. Y. As head of the Laboratory, he will be responsible for engineering development work in four fields: materials engineering, electrical engineering, engineering physics and analysis, and mechanical engineering.

A graduate of Massachusetts Institute of Technology (with a bachelor's and doctor's degree), he taught on the Harvard University faculty until World War II. After four years of Army service, he joined the G. E. Research Laboratories in 1946 and was appointed manager of the metallurgy and ceramics research department in 1952.

Dr. Hollomon has received wide recognition in his field; he holds the Rosenhain Medal for 1958 of the Institute of Metals in England, the Rossiter W. Raymond Award of A.I.M.E. and the Alfred Noble Award, and in 1954 he was named one of the country's leading young scientists.

Succeeding Dr. Hollomon as manager of the metallurgy and ceramics research department of the General Electric Research Laboratory is WALTER R. HIBBARD, JR. As recipient of the Yale Engineering Assoc. Award last year, he was cited as a "scientist and engineer, metallurgist of international reputation . . . [who] has carried over into his industrial research affiliation a continuing interest in the teaching of our youth."

A graduate of Wesleyan University, he received his doctorate in physical metallurgy from Yale in 1942 where he subsequently served as assistant and later as associate professor. A member of the staff of the Research Laboratory since 1951, he has been active in the leadership of the American Institute of Mining, Metallurgical and Petroleum Engineers and American Society for Metals.

Two years ago he was one of a group of American scientists who toured Russia under the sponsorship of the U. S. State Department, studying Soviet education and research in the field of metallurgy.

RALPH L. WILSON received the Ohio Society of Professional Engineer's highest award at the state convention last month. Mr. Wilson was cited for his leadership in the development of quality alloy steel for the antifriction industry and for his role in doing much to raise the status of the professional engineer in industry.

Director of metallurgy for Timken Roller Bearing Co. in Canton, Ohio, he has played a prominent part in the development of many steel compositions, manufacturing processes and methods; he was one of the pioneers in the development of steel compositions for elevated-temperature applications in pressure vessels and seamless tubing.

A graduate of Lehigh University (with a degree in electrometallurgy), he worked for United Alloy Steel Corp. and Central Alloy Steel Corp. before coming to Timken in 1929; he has been director of metallurgy since 1946.

Well-known to ASMembers, he has served as national trustee, vice-president and president of A.S.M. (see *Metal Progress*, June '53, p. 90).

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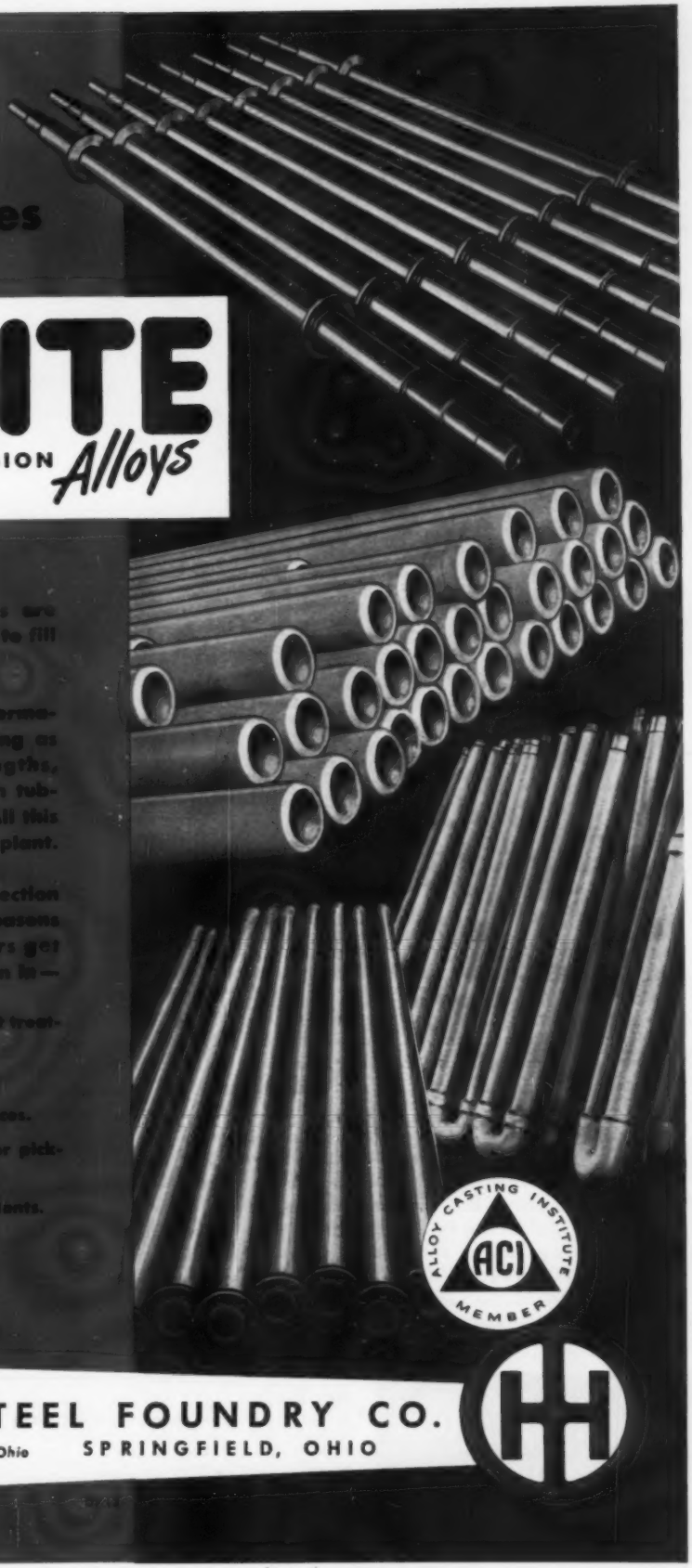

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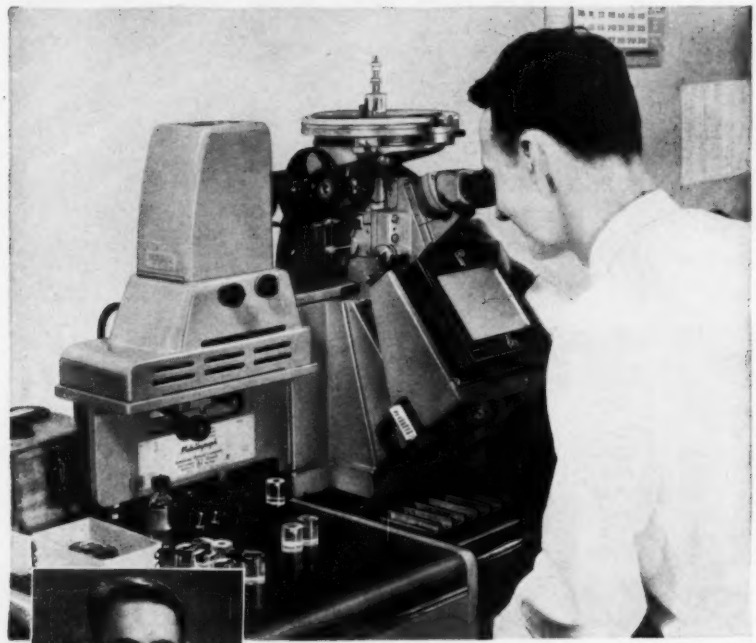

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Circle 1298 on Page 48-A

Personals . . .

Robert C. Harris – from chief research and development engineer, Arwood Precision Casting Corp., Tilton, N. H., to supervisory metallurgist, on the research staff of the Beryllium Corp., Reading, Pa.

John Geyer – from manager of the product development department, metalworking chemicals division, Amchem Products, Inc., Ambler, Pa., to technical assistant to the president.

Edward J. Dulis – from supervisor of high-temperature materials and welding research, Crucible Steel Co. of America, Pittsburgh, to the newly created position of manager of product research at the company's Central Research Laboratory. Mr. Dulis has administrative responsibility for the laboratory, a function formerly performed by **Peter Payson**, assistant director of research and manager of the Laboratory. Mr. Payson continues as assistant director but has relinquished his administrative duties to devote his major effort to writing a textbook on toolsteel metallurgy.

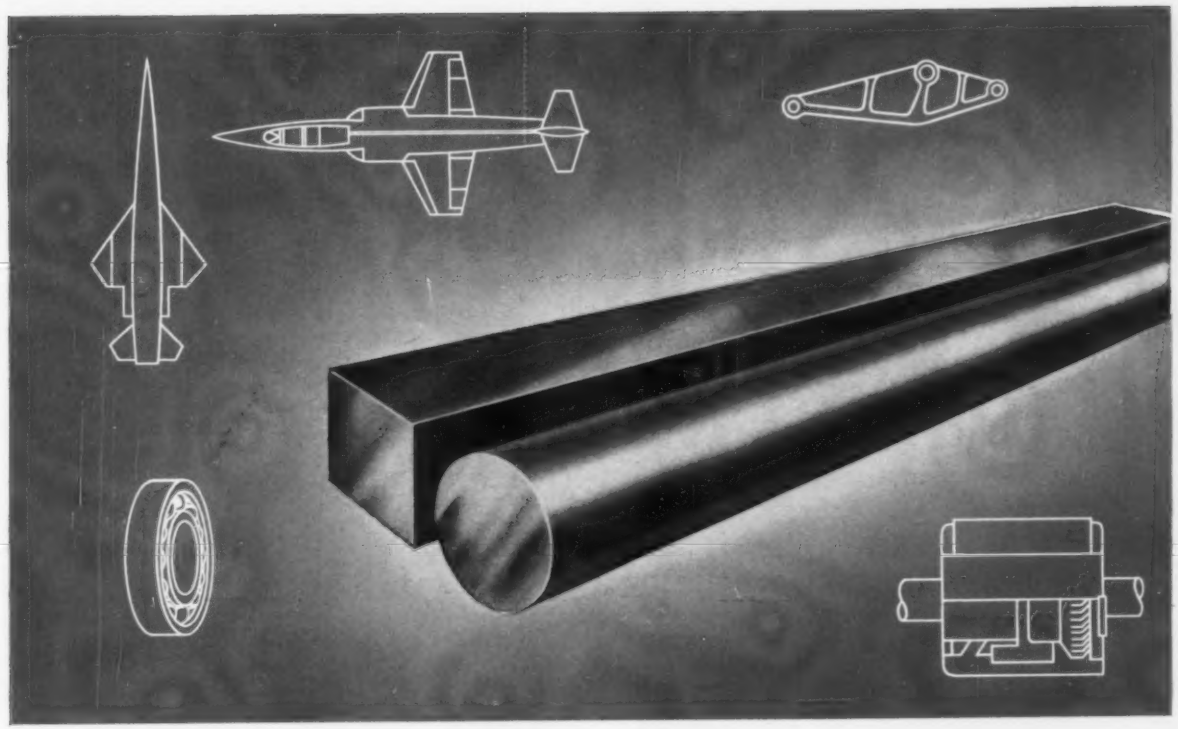
O. R. Carpenter – from manager, quality control section, Babcock & Wilcox Co., to assistant vice-president, boiler division manufacturing department.

Leslie E. Simon – resigned as vice-president and director of research and development of the Carborundum Co., Niagara Falls, N. Y.; now staff director of research and development of the company, acting as consultant to the president.

Augustus B. Kinzel, vice-president for research, Union Carbide Corp. – appointed chairman of the Division of Engineering and Industrial Research of the National Academy of Sciences-National Research Council.

G. M. Butler, Jr. – resigned as manager, engineering research branch of the research and development division of the Carborundum Co., Niagara Falls, N. Y.

John C. Cassidy – from project manager to manager of product projects for the American Car & Foundry Div., ACF Industries, Inc., New York.



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Circle 1300 on Page 48-A

Personals . . .

Carl C. Gobdel – from manager of stainless steel to district sales manager at the Philadelphia plant of Joseph T. Ryerson, Inc.

John L. Holmquist – to director of research, tubular products, for National Supply Co., with headquarters in Pittsburgh.

–Martin Perl – from senior research engineer, metallic materials laboratory, North American Aviation, to Superweld Corp., North Hollywood, Calif.

J. Donald FitzGerald – from sales representative for Copperweld Steel in Cleveland, to abrasive sales engineer for the Cleveland district of Pangborn Corp.

R. L. Pope – from manager of Cleveland sales district to manager of marketing research division of Union Carbide Metals Co.

Luther W. Cashdollar – elected vice-president of sales for Union Electric Steel Corp., Pittsburgh.

John P. Strand – from division superintendent, titanium, at Crucible Steel Co. of America's Midland (Pa.) Works to assistant director of the technical division of the company's technology department, responsible for the product development section.

Russel E. Frushour – retired as president of South Bend Lathe, Inc., a subsidiary of American Steel Foundries; remained a director of the company as well as a consultant.

J. G. Holmes – from assistant manager of the Pittsburgh region for Union Carbide Metals Co. to manager of the newly formed central sales region with headquarters in Cleveland.

Hiram Brown – from technical advisor to the vice-president and general manager of the Des Moines, Iowa, plant of Solar Aircraft Corp. to consultant to the department of metallurgy, Battelle Memorial Institute, Columbus, Ohio.

Hal Shidemantle–from manager of engineering services, Jack & Heintz, Inc., Cleveland, to manager, engineering materials laboratory, Mack Trucks, Plainfield, N. J.

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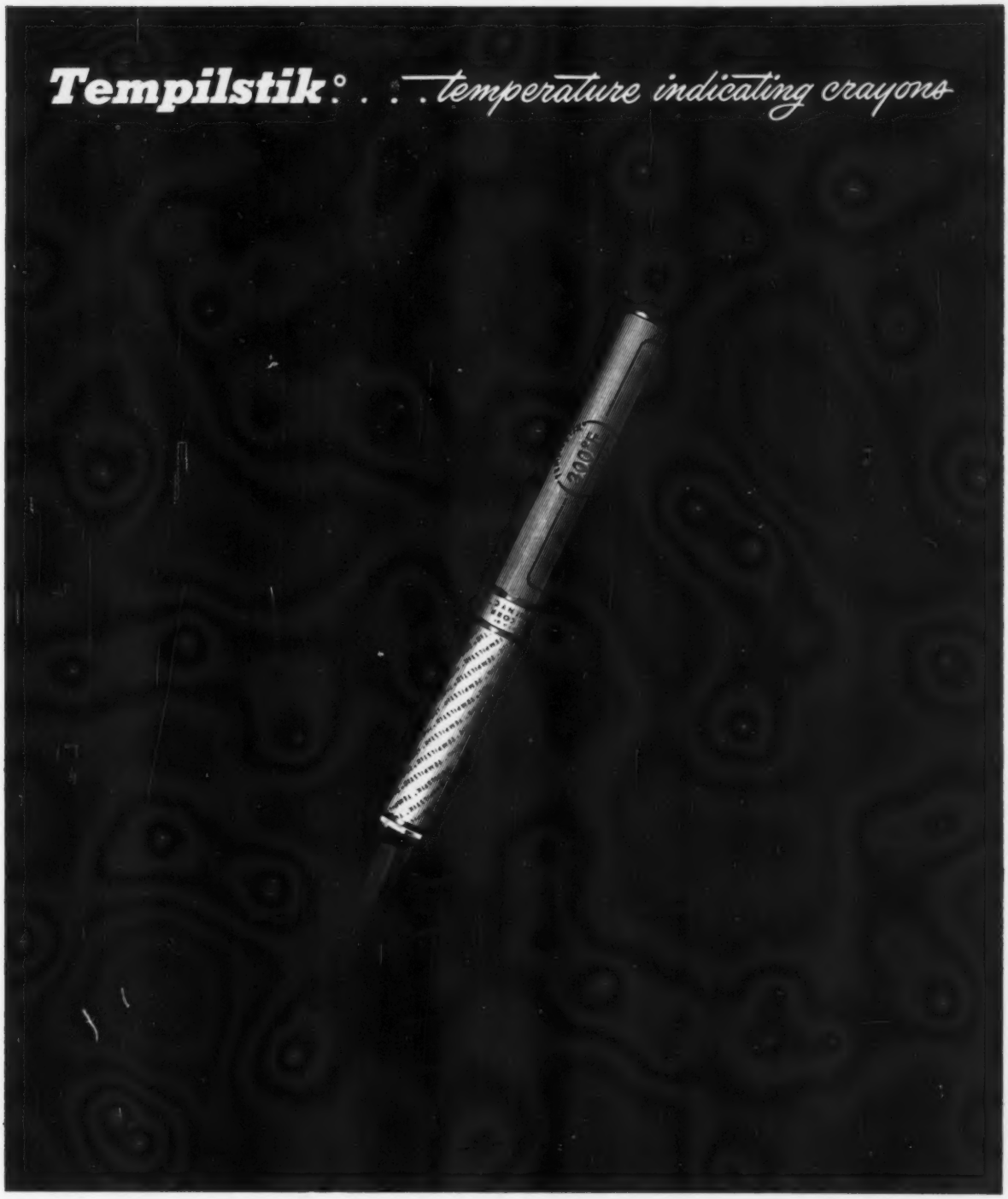

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Circle 1301 on Page 48-A

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

How Wear Is Influenced by Surface Finish

Digest of "The Significance of Surface Finish on Friction Wear and Lubrication", by A. Sonntag. Paper presented at Seminar on Friction, Lubrication and Wear, Lucerne, Switzerland, September 1959.

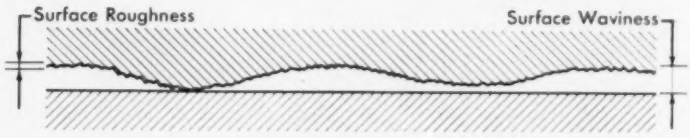
THE AVERAGE HUMAN EYE can barely see a wire 1000 micro-in. in diameter. Yet the essential details of surface geometry which affect friction and wear behavior range from this size downward. If the mating surfaces in bearings could be made so smooth that surface irregularities would be reduced to the lattice spacing of surface atoms (2 to 4 Angstroms) and free of contaminating films, mere pressure could produce cold welding. Thus smoothest and cleanest surfaces are theoretically the worst possible for boundary lubrication conditions.

Fortunately, the attractive forces between atoms diminish with the sixth power of distance of separation. Separation of contacting surfaces by 1 Angstrom is sufficient to reduce the forces of attraction between surface atoms to a negligible quantity.

During hydromatic lubrication, liquid films as thin as 10 micro-in. can separate bearing surfaces. The height of surfaces peaks or asperities in the mating surfaces limits the minimum thickness of such continuous lubricant films. Theoretically, extremely high bearing loads could be supported in hydrodynamic bearings if the minimum film thickness were not limited by asperities piercing the film and contacting.

Surface waviness is probably more undesirable than surface roughness.

Fig. 1 – Difference Between Surface Roughness and Surface Waviness. The latter is probably more undesirable



The difference between these two classes of surface irregularities is important and is shown in Fig. 1. Reduced damage would be expected if all the surface asperities were in the same plane, thereby increasing the number of possible initial contacts. Finishing surfaces with improved surface geometry, therefore, begins with the reduction of waviness – something that is virtually impossible to accomplish by the "wearing-in" process.

It has long been known that, when boundary lubrication conditions prevail, roughened sliding surfaces will often perform better than ultra smooth ones. Recent experiments by the author have shown that not only the degree of roughness but also the geometry of the microscopic hills and valleys on the bearing surfaces influence the wear and friction behavior.

These experiments were performed using steel specimens treated with bonded solid lubricant. Both ground and sand-blasted surfaces were wear tested. A range of roughnesses (10 to 70 micro-in. rms.) was investigated for both types of surface finish. Results of these tests demonstrated that wear life of the lubricant film on surfaces within 10 to 50 micro-in. rms. was from 2 to 20 times longer on sand-blasted surfaces than on ground surfaces (see Fig. 2).

The significant improvement in wear life of the lubricant film could not be entirely attributed to better bonding of the lubricant coating, according to the author. Accurate film thickness measurements indi-

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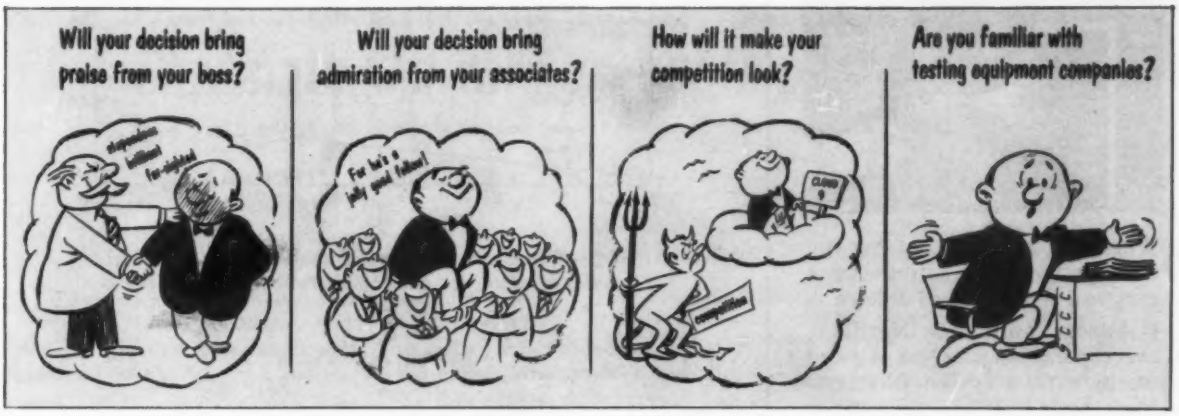
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The Hallmark of Quality in nondestructive test systems

Circle 1302 on Page 48-A

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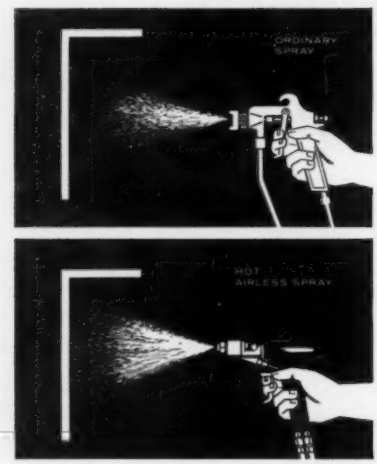

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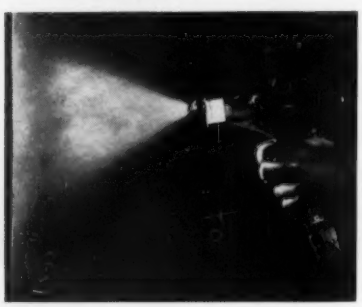

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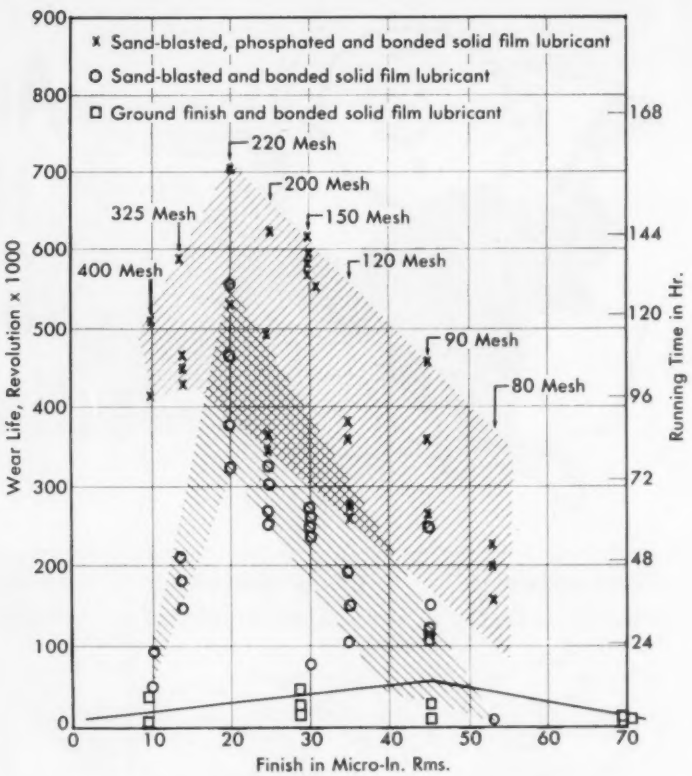

Fig. 2 — Wear Life and Surface Finish. Note that sand-blasted surfaces wear much longer than ground finishes

cated that metal-to-metal contact of surface asperities started before full load was applied during the wearing-in period of the wear test.

The author suggests that the geometry of the surface asperities formed by sand-blasting is an important factor in wear behavior observed. Sand-blasting produces asperities of approximately pyramidal shape. Grinding produces continuous ridges in the surface. If the ridges left by grinding contact and cold weld along their long dimension in the direction of sliding, the junctions have high resistance to shearing forces during sliding. Breaking of these junctions causes ploughing of the surfaces, leaves wire edges, and produces long slivers and curled "chips" as wear debris. The wear debris produced by ground surfaces gives rise to more surface damage. Cold welding of contacting pyramidal asperities, on the other hand, will produce junctions which can be more easily sheared in the direction of sliding. Smaller, rounder wear debris also results. In the pyramidal surface structure, the valleys are all interconnecting, forming a more efficient capillary system for lubricant distribution to the load areas. Experiments also demonstrated that there is an optimum height for surface peaks caused by sand-blasting.

W. A. GLASER

Austenitic Stainless Steels

Digest of "Relationships Between Composition and Properties of Austenitic Chromium-Manganese - Carbon - Nitrogen Stainless Steels", by A. Kasak, C. M. Hsiao and E. J. Dulis, A.S.T.M. Preprint No. 74. Paper presented at the 62nd Annual Meeting of A.S.T.M., June 1959.

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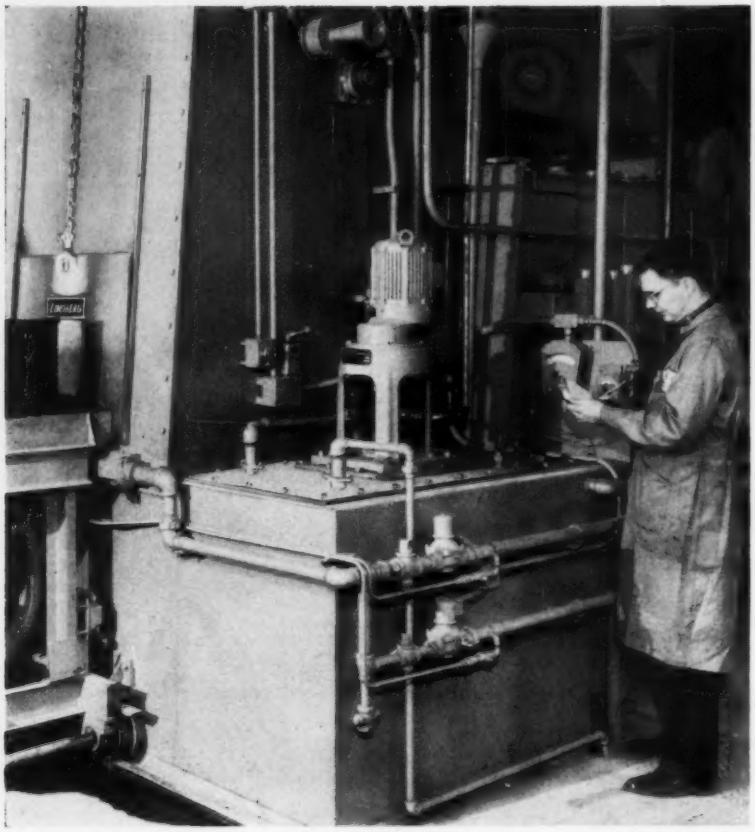

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Circle 1305 on Page 48-A

Austenitic Stainless . . .

ing, aging, or service temperatures. A completely austenitic structure can be obtained if $C + N = 0.078\ (Cr - 12.5)$*. Addition of 12 to 15% Mn stabilizes the austenite against transformation to martensite during cooling.

Room temperature strengths can be predicted by the equations:

Tensile strength, psi. =
$88{,}400 + 53{,}300\ (1.5\,C + N)$

Yield strength (0.2% offset), psi. =
$34{,}000 + 53{,}500\ (C + 1.2\,N)$

Chromium and manganese have little effect on the tensile properties for steels having compositions within these ranges: 0.09 to 0.82% C, 0.11 to 0.78% N, 12.24 to 27.98% Cr, 10.31 to 15.75% Mn. With proper composition and heat treatment, these steels have tensile elongations of 55 to 70% and reductions in area of 50 to 75%.

Stress-rupture strengths (100 hr.) for these alloys are greater than for Type 316 stainless steel. A few of these alloys have a greater stress-rupture strength than does the 16 Cr, 25 Ni, 6 Mo alloy. There are indications that rupture strength is related to the amount of carbon and nitrogen dissolved in austenite rather than to the total amount of carbon and nitrogen in the steel.

Stable austenitic Cr-Mn-C-N steels may be designed by the following procedure:

1. Determine the amount (%) of chromium required for the indicated service conditions (for example, the temperature and the allowable oxidation).

2. From this amount (%) of chromium required and the following equation, calculate the combined amount (%) of carbon plus nitrogen needed:

$$C + N = 0.078\ (Cr - 12.5)$$

3. Proportion the amounts of carbon and nitrogen with regard to *(a)* the amount of nitrogen that could be put into the steel during melting by conventional methods, *(b)* the solution-annealing temperature, and *(c)* the desired room-temperature strength and ductility.

4. Stabilize the austenite against transformation to martensite by adding about 12% Mn when the chromium content is over 15% and 12 to

*All compositions are in weight percent.

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Austenitic Stainless . . .

18% Mn when the chromium content is less than 15%.

5. Estimate the room and elevated-temperature strengths. These strengths can be controlled by changing the amount of carbon and nitrogen.

6. Increase the contents of chromium or manganese or both (and thereby the nitrogen solubility) if the amount of nitrogen desired is beyond the limit that could be put into the steel during melting.

A nomograph has been developed to facilitate compositional design of stable austenitic Cr-Mn-C-N steels and estimate of room and elevated-temperature strengths of these steels.

C. O. SMITH

Mechanical Properties Affected by Specimen Size

Digest of "The Effect of Specimen Size on Tensile Properties of Coarse-Grained Medium Carbon Steel at Low Temperatures", by T. Williams and H. F. Hall, *Journal*, Iron and Steel Institute, September 1959, p. 56-60.

THIS INVESTIGATION was undertaken to study whether at low temperatures the size of tensile specimens altered properties when contrasted with those observed at room temperature. (Size effect has been investigated before, though chiefly at room temperature in mild steel.) In this investigation, a British steel (0.43% C, 0.13% Si, 0.65% Mn) was used. The material was annealed at 1650° F. (900° C.) to develop a large grain size conducive to the production of brittle fractures at low test temperatures. The duplex grain size was about 70% No. 3 grains and 30% No. 6 grains, as noted by A.S.T.M. Standards.

The test pieces used were of eight different cross-sectional areas varying from 0.01 to 0.33 sq.in. They were made geometrically similar with a parallel length of $5\sqrt{\text{area}}$. Two further sets of specimens were made relatively longer; one, 0.0625 sq.in., had a parallel length of $13.25\sqrt{\text{area}}$, and the other, 0.125 sq.in., a length of $8.5\sqrt{\text{area}}$.

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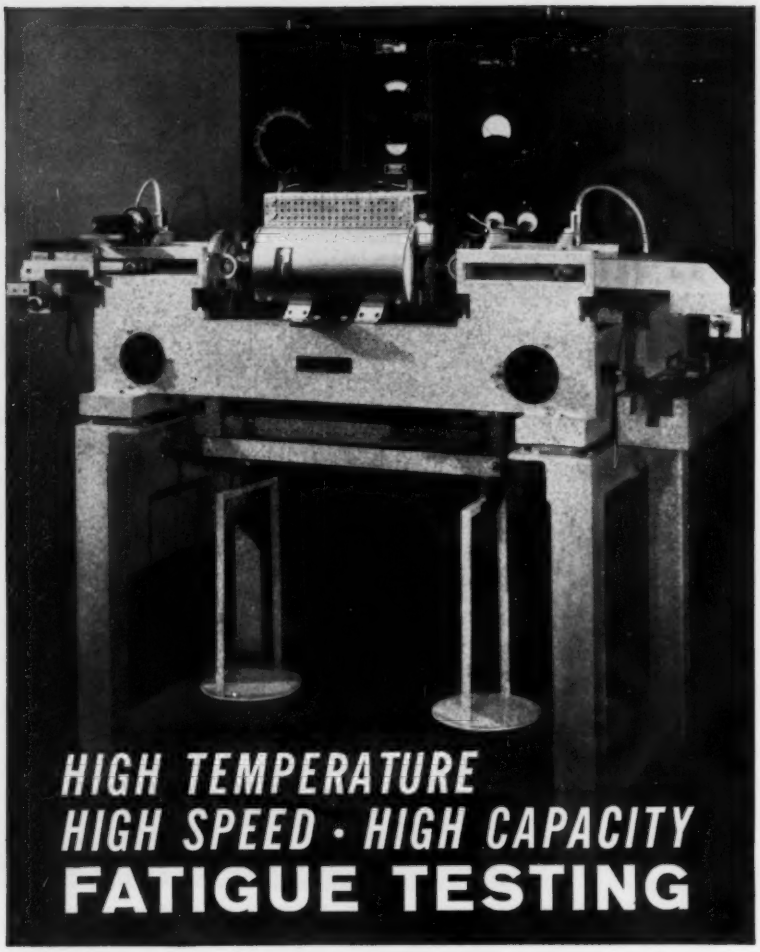

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Circle 1309 on Page 48-A

Mechanical Properties...

reduction in area were made when the fractured test pieces had regained room temperature. The elongation values were always measured on the standard gage length of $4\sqrt{\text{area}}$. These and other mechanical properties were measured at +20, −50, −100, −120, and −196° C. (+70, −60, −150, −180 and −320° F.).

Results

The ultimate stress and yield point increased continuously with decrease in temperature and were similar for each size of test piece. However, the reduction in area showed a continuous decrease which was very slight immediately below room temperature but became very marked below −100° C. (−150° F.). The elongation generally showed a slight increase down to −50° C. (−60° F.) with exceptions among the smaller specimens. With further decrease in temperature, there was a continuous decrease of elongation in conformity with the variation of the reduction in area. The effect of specimen size on the reduction in area and elongation are shown by several graphs in the paper.

These curves indicate that the reduction in area value generally increased as the test piece size was reduced, for all test temperatures, whereas elongation values were not affected significantly until a temperature of −100° C. (−150° F.) was reached. In both instances, the maximum effect occurred at −120° C. (−180° F.).

The type of fracture showed a considerable size effect at room temperature, the larger test pieces showing smaller amounts of fibrous fracture than the smaller specimens. This effect was also present at −50° C. (−60° F.) although to a lesser extent. At lower temperatures, the tensile fractures were usually completely crystalline.

A thorough survey of all the tests indicate that size effect was influenced by temperature only in respect to those properties related to *strain*, and the effect was only marked when the temperature was between prescribed limits. For the properties related to *stress*, there was no variation of size effect with temperature. A tendency to embrittlement with

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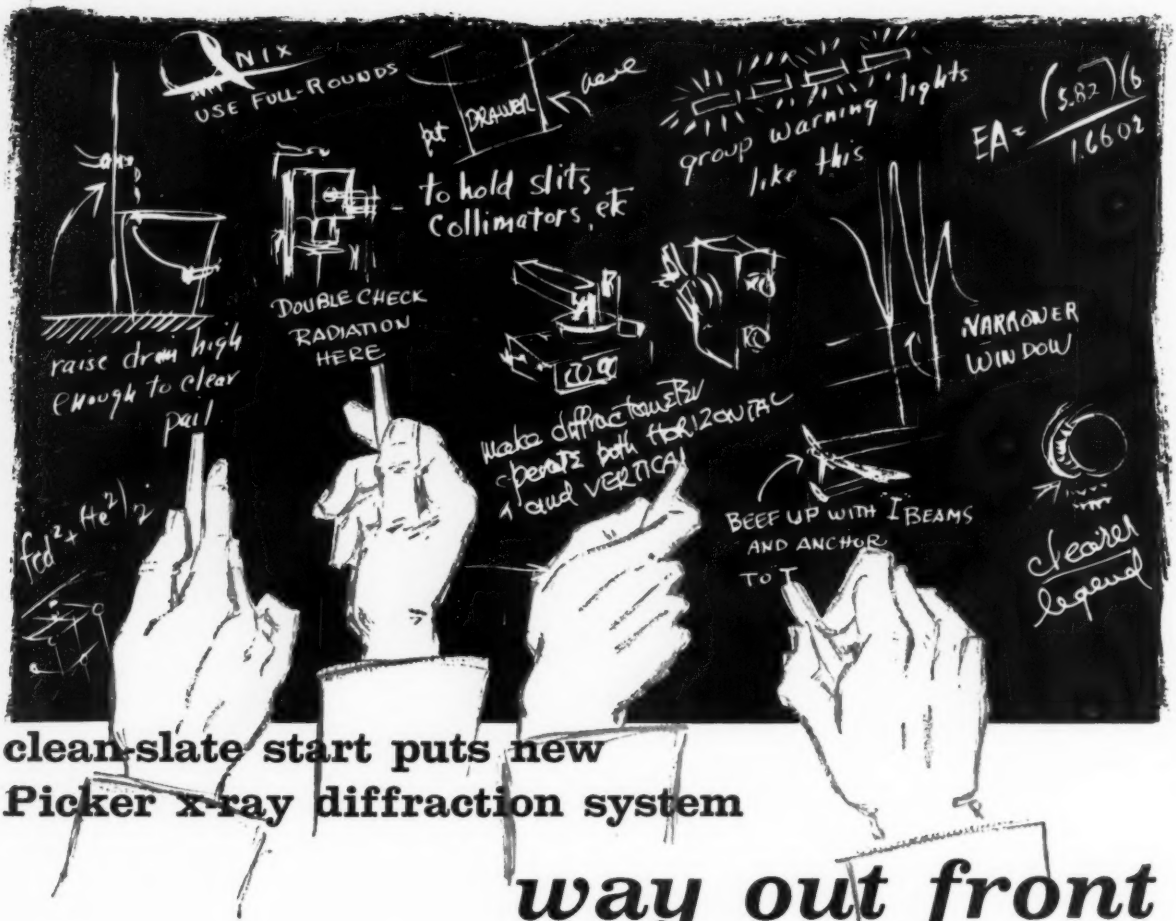

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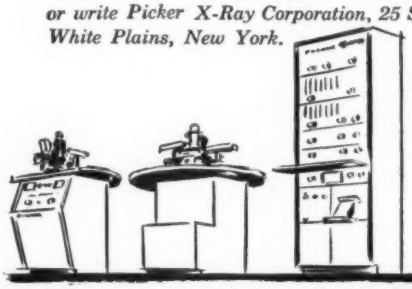

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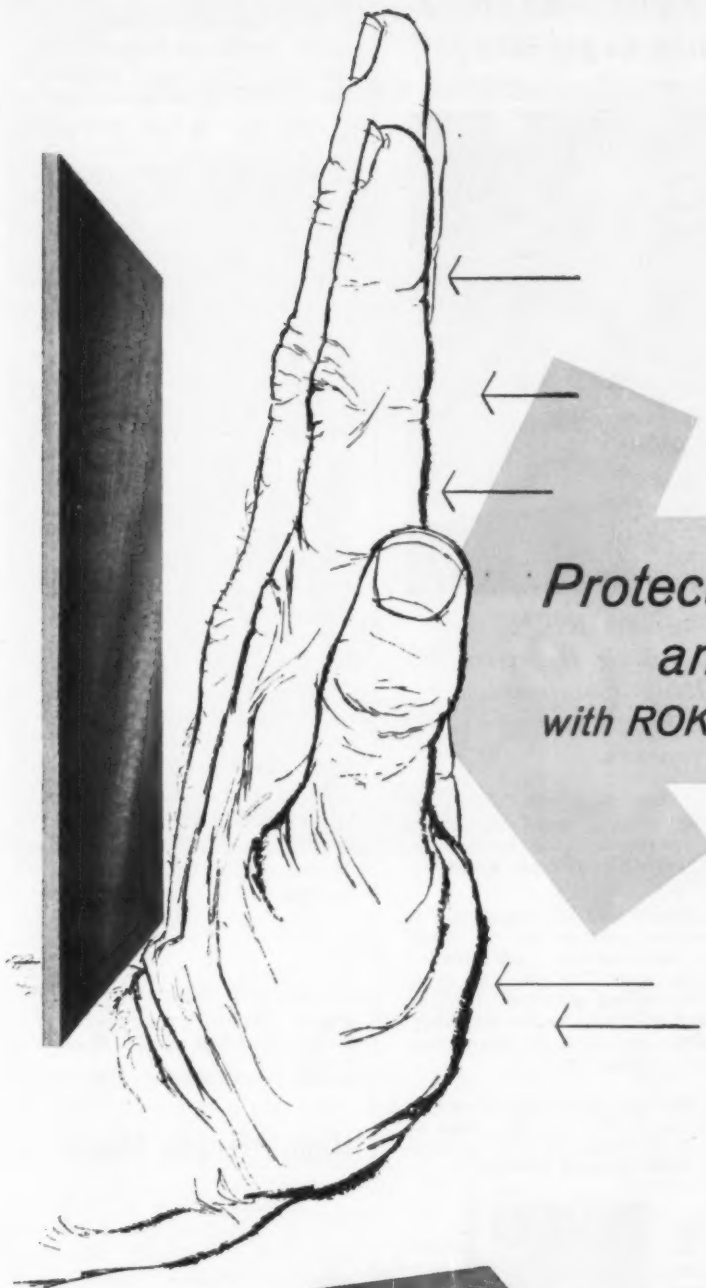

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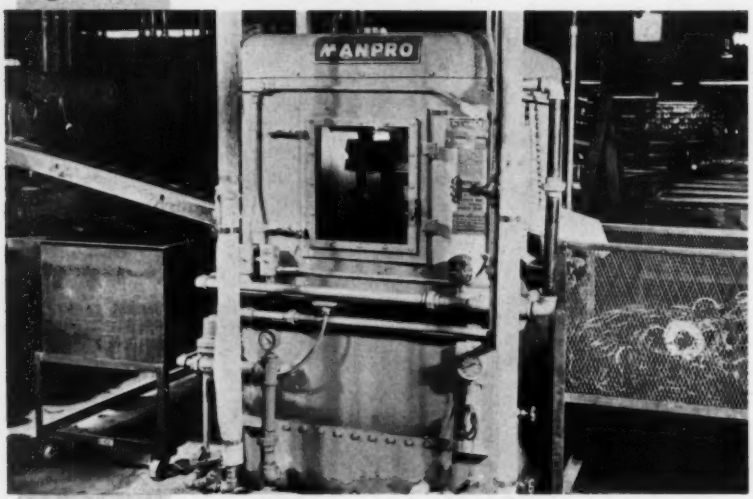

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Circle 1352 on Page 48-A

Mechanical Properties...

increase in specimen size was, therefore, the only appreciable size effect on the mechanical properties to be observed. The critical temperature for this material was −120° C. (−180° F.). At this temperature, as the test pieces decreased in size from 0.25 to 0.01 sq.in., elongation and reduction in area values increased from 10.7 and 11.2% to 26 and 32%, respectively.

This effect of specimen size may be explained if it is assumed that failure starts from a pre-existing defect or crack. In a larger test piece, the probability of encountering one of these defects is greater.

The fractures of the broken test pieces showed a considerable size effect at room temperature, with the degree of fibrous fracture becoming progressively less as the specimen size increased. The proportions of fibrous to crystalline fracture varied continuously with the volume of the test piece (in other words, gage length and area of cross section). This suggests that the greater the stored energy per unit area of fracture the greater was the fracture speed and the embrittling effect.

The findings in this investigation are in general agreement with the great deal of work that has been carried out in the past on brittle fracture.

W. A. MORGAN

MP *Golden Gate Metals Conference Report*

High-Strength Steels...

(*Continued from p. 68B*)

G. R. Irwin, U.S. Naval Research Laboratory, presented the third paper on "Fracture Toughness of High-Strength Steel Pressure Vessels", with J. A. Kies as co-author.

The basic viewpoint advanced by Mr. Irwin's theoretical consideration hinges on the assumption that an approximate, but quantitative, evaluation of failure of a pressure vessel by general yielding may be made by comparing the net section stress to yield stress. Such a stress equivalence hypothesis envisages two

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Circle 1353 on Page 48-A

High-Strength Steels . . .

regimes of material behavior considering the crack length in a specimen (or pressure vessel) versus the net section stress: (*a*) For small crack lengths, the net section stresses remain essentially unchanged, and (*b*) beyond a certain crack length, the net section stress decreases in proportion to the inverse square root of the initial crack length.

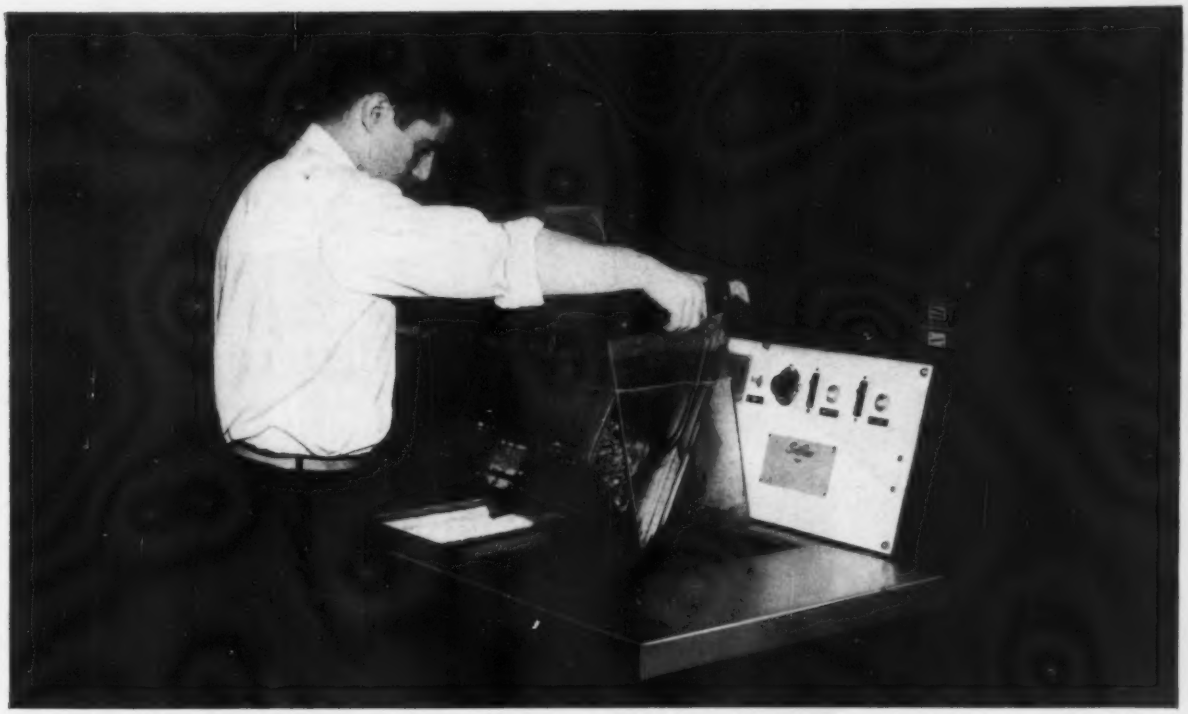
Considering that a certain amount of plastic deformation generally accompanies extension of cracks in all materials, a prediction of tensile failure requires knowledge of the extension of a crack across the net section without regard to the plastic deformation.

Dr. Irwin explained that experimental investigation of crack propagation in terms of stress intensity factor K or strain energy release rate G is facilitated by the fact that the speed of crack extension is sensitive to the force applied. Therefore, critical values Kc and Gc, characterizing onset of rapid crack extension, can be defined and measured using a method similar to that used for determining yield stress required for rapid plastic yielding.

Dr. Irwin next showed the variation of Kc with plate thickness and explained that the dynamic elevation of yield stress occurs with reduction of plate thickness during the approach toward fracture mode transition from flat-tensile to shear-type behavior. In applying the above theory to failure analysis, he indicated that Gc values are helpful in deciding the causes of fracture in terms of low fracture toughness, high stress and large flow size. In laboratory fracture toughness tests, Dr. Irwin emphasized the use of wider specimens since the plastic zone size controls the fracture transition.

In summing up his talk, Dr. Irwin made the following recommendations: The minimum Gc values in weldments should be 800 lb. per in. with higher values in the cylindrical wall of the missile chamber.

The fourth paper was presented by Dean K. Hanink, Allison Div., General Motors Corp., entitled "Metallurgical Tests as a Contribution to Pressure Vessel Reliability." The speaker reiterated that a thorough testing program should be an adjunct to making a reliable and



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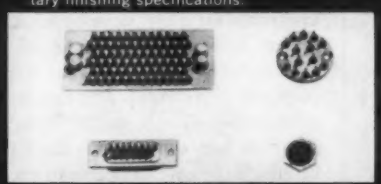

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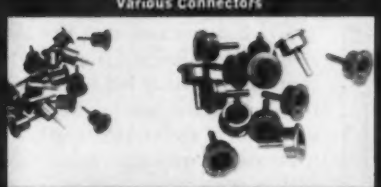

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According to Mr. John Newman, Chief Chemical Engineer at Glass-Tite, the Autronex Acid Gold Electroplating Process was installed because it demonstrated dramatic superiority over other materials. On one occasion, Mr. Newman relates, Autronex Gold Plated Transistor-Headers were left in the CP-4 etch solution *overnight*—"... just to see what would happen." By morning, the glass seals had dissolved, the Autronex Gold Electroplate had not been affected.

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Circle 1355 on Page 48-A

High-Strength Steels . . .

reproducible pressure vessel.

The test developed by Mr. Hanink is a simple beam bend test in which the angle of bend to first crack and the rate of load decrease due to crack progression are measured. This test, according to the speaker, can be used to correlate directly a bend test parameter and hoop burst strength of pressure vessels. The test can also be used for quality control of the raw material in billet form at the steel mill, as well as control of subsequent fabricating and heat treating operations. Based on the results of these tests, Mr. Hanink indicated a preference for vacuum-remelted material over air melted stock for constructing reliable missile motor chambers. (More details will be given in a future issue of *Metal Progress*, presenting many of the complete papers from this session.)

The second session on "High-Strength Steels for the Missile Industry" was presided over by H. L. Anthony III, Mellon Institute, and C. E. Johnson, Lockheed Aircraft Corp. Dr. Anthony, in his opening remarks, stressed the need for new high-strength steels which will have none of the deficiencies associated with currently available materials. He cited the alloy work being carried out at Mellon Institute and hoped it would lead to other research programs on alloy development.

The first technical paper of this session, presented by G. B. Espey, National Aeronautics and Space Administration, dealt with "N.A.S.A. Program and Findings on the Effect of High Stress Concentrations on High-Strength Sheet Alloys."

Mr. Espey stated that the use of heat treated alloy steels at very high strength levels has led to difficulties from brittle fracture at stresses only a fraction of the yield strength. This is associated with embrittling factors such as stress concentrations (a principal factor), high loading rates, hydrogen embrittlement, large size and loss of toughness at low temperatures. The contributory effect of internal flaws increases rapidly with increase of strength level of the steel. In other words, smaller flaws become major defects at high strength levels.

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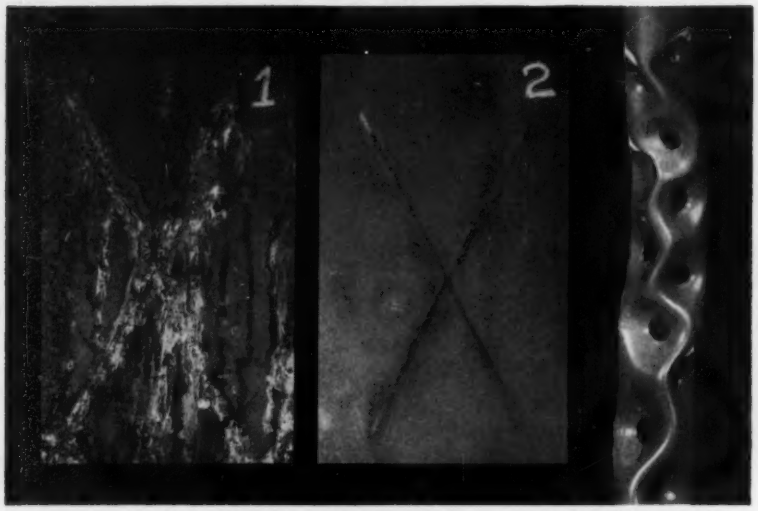

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High-Strength Steels . . .

means for evaluating a given material under very high stress concentrations. In conjunction with data obtained from unnotched tensile specimens, this test provides an indication of the ability of a material to withstand high stress concentrations by plastic yielding.

A considerable amount of sharp-notch tensile test data developed on steel and titanium alloys at N.A.S.A. was presented by Mr. Espey. The use of a notch stress concentration ratio of 17 was recommended. The speaker placed particular emphasis on the ability of this test to reveal embrittlement ranges associated with heat treatment. This test, however, did not indicate the superiority of vacuum melted steels over good air melted sheet steels.

The next paper, presented by G. K. Bhat, Mellon Institute, introduced a new ultra-high-strength steel suitable for manufacture of high-performance rocket motor cases. The steel is A.I.S.I. 4100 type modified with additions of cobalt and silicon. A typical analysis* manufactured by Universal-Cyclops Steel Corp. (Unimach UCX 2) has a 0.2% offset uniaxial yield strength of 225,000 to 235,000 psi.

The more important asset of this steel (termed A.I.S.I. 4137 Co) is that it retains all the good fabrication qualities characteristic of A.I.S.I. 4100 series steels with improved weldability as well. In welding large missile chambers, ease of material movement in order to achieve thoroughly matched and aligned joints is essential to eliminate stress-raisers. This steel has this ability. The welds produced are clean, tend to be equiaxed in grain structure and the weldment upon heat treatment develops strength equivalent to the rolled parent metal.

The steel has hardenability required to quench it to a 100% martensitic structure in the thickest component sections in a high-performance missile chamber.

The development of the steel was based on the experience derived from testing A.I.S.I. 4137 and medium alloy H-11 type steels. Dr.

*The nominal composition of this steel is 0.39 C, 0.70 Mn, 1.00 Si, 1.10 Cr, 0.25 Mo, 0.15 V, and 1.00 Co.

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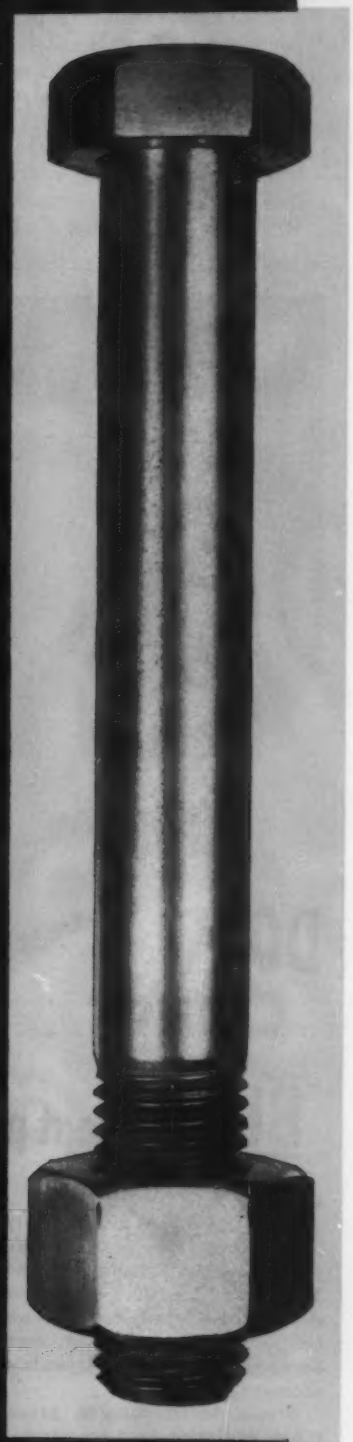

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Circle 1358 on Page 48-A

High-Strength Steels . . .

Bhat next showed comparative uniaxial and biaxial test data. A point was made that, although the burst pressure of H-11 steel chambers was high, the biaxial yield strength was significantly lower than that of A.I.S.I. 4137.

Dr. Bhat presented notched bar tensile test data for this steel which indicated the relative insensitivity of 4137 cobalt steel to notch brittleness. Results of multiaxial tests conducted on ellipsoidal cups indicated the good biaxial strength capability and reproducibility of results on vessels of all sizes including a 4½-ft. diameter flight design test chamber.

Dr. Bhat concluded his talk with a remark that this steel should be of considerable interest to builders of missiles and other space vehicles for applications involving strength levels of 225,000 to 235,000 psi., 0.2% offset uniaxial yield or 240,000 to 245,000 biaxial yield. (In the June issue of *Metal Progress* Dr. Bhat will give a complete story on the development of this new steel.)

The final paper of this session was presented by Eugene P. Klier, Catholic University of America (formerly of the National Academy of Sciences), on "Important Factors in the Future Applications of High-Strength Steels".

Dr. Klier at the very outset of his talk pointed out that the most important need today lies not so much in determining notch sensitivity of materials for the construction of missile motor cases, but in the development of steels which have improved notch toughness at yield strengths above those now available.

Commenting upon the fracture mechanism in high-strength materials, Dr. Klier stated that at least three different mechanisms are recognized, namely, low-energy shear, high-energy shear and flat brittle fracture. Low-energy shear is commonly observed in 4300 series steels, whereas high energy shear, which is more desirable, is evidenced in steels tempered around 1000° F. Dr. Klier emphasized that any notch test which does not recognize the failure mechanism leaves much to be desired. The importance of metallurgical structure in determining notch sensitivity, fracture toughness and strength was pointed out.

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Circle 1359 on Page 48-A

MP *Golden Gate Metals Conference Report*

Brazing . . .

(Continued from p. 68D)

penetration into the René 41 down to a minimum, and brazes at 2150° F. Although J-8600 produces a relatively brittle joint, it was described as being more ductile than the J-8100 alloy or Nicrobraz. The present cost of the J-8600 alloy is around $150 per lb. Some parts of brazed René 41 are being used in the J-79 turbojet engine; they have shown better strengths above 1500° F. than either A-286 or Inconel 702.

Mr. Huschke commented that if René 41 is properly brazed with the new J-8600 filler alloy, its maximum loss in tensile strength is less than 10%. High-vacuum brazing tech-

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X-ray of a one-quarter inch thick beryllium weldment.

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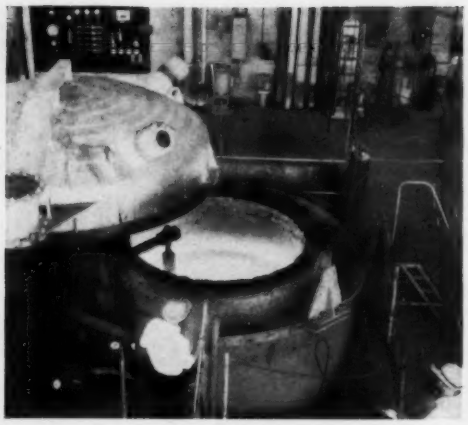
Circle 1360 on Page 48-A



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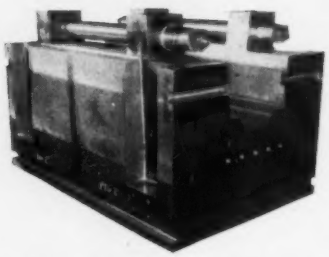

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Circle 1361 on Page 48-A

Brazing . . .

niques are preferred, although nickel-plated René 41 has been satisfactorily brazed in dry hydrogen.

According to N. Bredzs, Armour Research Foundation, the ideal structure for a stainless steel joint brazed at high temperature is complete atomic diffusion across the base metal interface without a filler metal layer between. If (as is usually the case) a filler metal must be used, it should be diffused as completely as possible into the base metals. Diffusion of brazing filler metals frequently begins as grain-boundary penetration into the base materials, then continues as a general alloying or diffusion into the metal grains themselves. The degree to which this is achieved is a function of time and temperature.

The approach to developing a high-temperature brazing filler alloy is to aim for a brazing alloy with the highest possible remelt temperature (when the brazed joint is reheated after brazing).

Work at Armour on increasing remelt temperatures followed two main approaches: *(a)* by alloying the filler metal with the base metal; *(b)* using high melting metals, and adding volatile elements which form relatively low-melting eutectics. After melting, the volatile elements are removed from the joint by vaporization, giving a high remelt temperature for the resulting bond.

Mr. Bredzs commented that the alloying method is relatively slow, while the volatilization technique is quite rapid. An example of the volatilization technique is the use of a nickel-indium filler alloy. Although nickel melts at 2651° F., and indium at 313° F., the low-melting binary eutectic nickel-indium alloy melts and brazes at around 1667° F. During the brazing cycle, the indium is volatilized and removed from the joint. This raises the remelt temperature of the remaining filler metal toward the melting point of nickel.

The investigation made by Mr. Bredzs covered a range of filler alloy compositions containing nickel, chromium, germanium, iron, lithium, and phosphorus. Of the alloys studied, a 61% Ni, 39% In composition showed the greatest rise in remelt temperature using the volatilization technique. A 94% Ni, 6% P alloy gave

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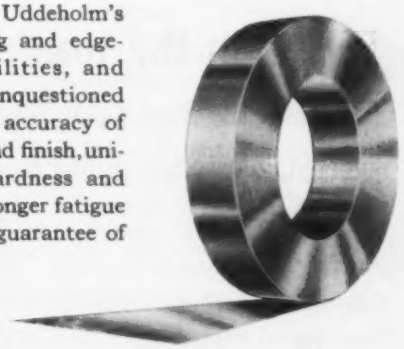

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Circle 1362 on Page 48-A

Brazing . . .

the greatest rise in remelt temperature through alloying and diffusion with the base metal. Some nickel-chromium-indium-germanium alloys indicated appreciable rises in remelt temperatures through both volatilization and alloying mechanisms.

In a paper entitled "The Horton-clad Process of Vacuum-Pressure Brazing", D. C. Bertossa, Chicago Bridge and Iron Co., discussed the development of an unusual brazing technique for the integral and continuous bonding of large surface areas. The process employs high-vacuum techniques to provide both deoxidizing effects to the bond interfaces and the high uniform pressures necessary for intimate contact at the bond interfaces during brazing. High-strength brazed joints can be effected with both similar and dissimilar metals without deforming the parent materials.

In addition to joining ordinary metals and alloys (carbon steels, stainless steels, high-nickel alloys), the vacuum-pressure process has been used for high-strength bonds with metals such at titanium, zirconium, tantalum, molybdenum, silver, gold, platinum, and others.

MP ***Golden Gate Metals Conference Report***

Metal Processing . . .

(Continued from p. 68D)

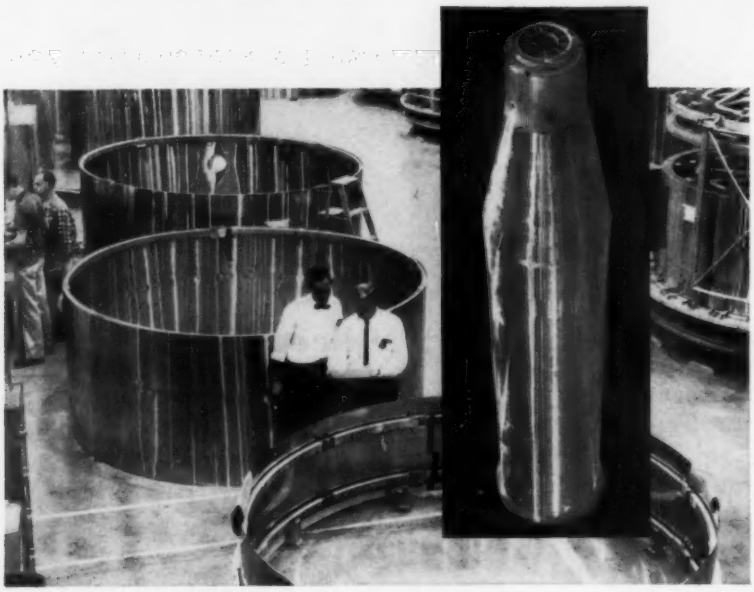
method of melting is now fairly well understood. Its major advantages appear to be the production of metals and alloys for use at high temperatures or high stresses.

Mr. Hunt predicted that electron beam melting would rapidly take its place as an integral part of many metallurgical cycles. He looks for wide industrial use of the process for melting nickel superalloys to give high ductility and for melting high-strength steels for low notch sensitivity. The electron beam method is useful for processing columbium, tantalum and hafnium; for melting high-purity alloys such as 90% tantalum, 10% tungsten, and columbium with 1% zirconium; and for producing molybdenum with low carbon and low oxygen. It will process welding wire alloys to give less than 80 ppm. of sulphur and phosphorus.

Mr. Hunt feels that the electron beam method will be widely used for scrap remelting. As new equipment enters the field, ingot size will increase and costs will go down. For example, in 1960, ingots 6 to 8 in. in diameter can be melted; during 1961, ingot diameter will increase to 12 to 16 in., with melting costs only one third what they are today. In 1962 he predicted ingots 20 to 24 in. in diameter – perhaps even up to 30 in. – with considerable use of the process for the less critical alloys. Estimated cost for melting large ingots: some 20¢ per lb. for steels and nickel-base alloy, 50¢ for columbium and molybdenum, and 75¢ for tantalum.

Ultrasonics Vibrations Refine Grain Size

D. H. Lane, Westinghouse Electric Corp., told the Conference that laboratory and pilot-plant experience



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*ATLAS—The Story of a Missile
by John L. Chapman, ©1960

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Circle 1363 on Page 48-A

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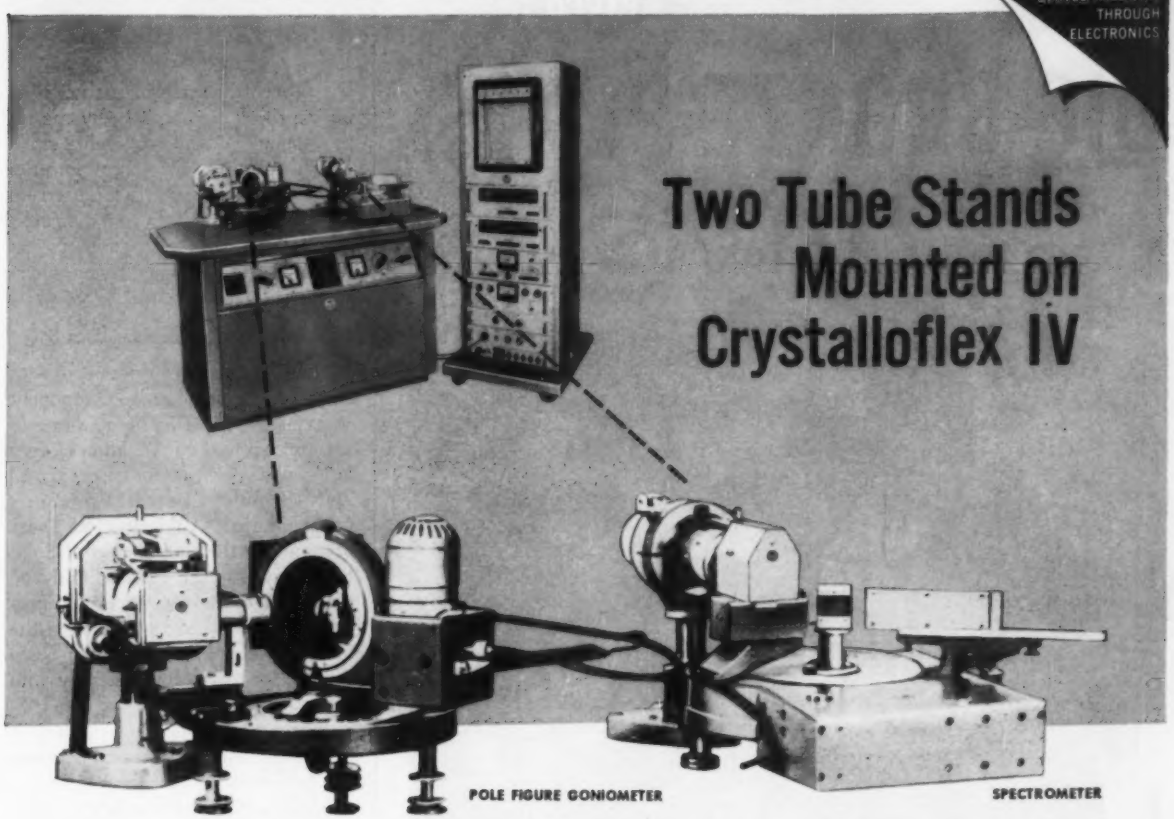

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Conveniences such as this, as well as unusual flexibility and fine craftsmanship, are making this RCA equipment one of today's most frequently specified lines. Installations have already been made in a number of the nation's foremost research laboratories where these instruments are demonstrating their efficiency and versatility.

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Service and installation supervision on all RCA Scientific Instruments are available everywhere through the offices of the RCA Service Company, Inc.

For further information, write to Radio Corporation of America, Dept. F-72, Building 15-1, Camden, N.J. In Canada: RCA VICTOR Company Limited, Montreal.

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Circle 1364 on Page 48-A

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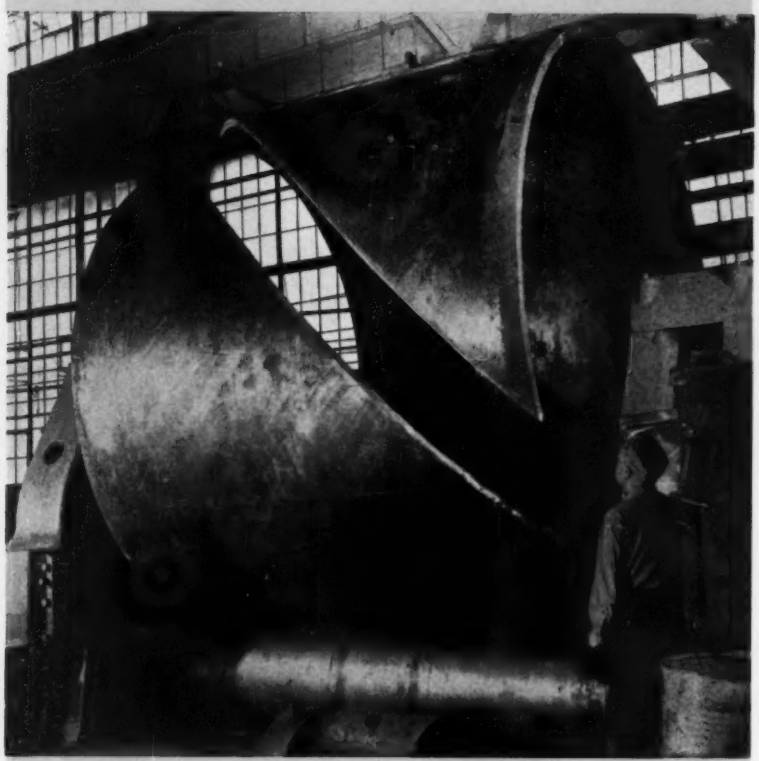

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An Ampco Metal Tube Sheet 2" thick can be rolled 10'-6" in diameter. One 3" thick can be 9'-0" in diameter.

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e-23c

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West Coast plant: Burbank, California
Southwest plant: Garland (Dallas County), Texas

Circle 1365 on Page 48-A

Metal Processing . . .

has proved that ingot structure may be improved significantly by the introduction of a relatively small amount of ultrasonic energy into the ingot. The process can be used on ingots at least 12 in. in diameter. Normally difficult-to-forge alloys can be made more forgeable by ultrasonic grain refinement.

Shear Spinning Rocket Cases

On the basis of experience with shear spinning small component parts, it appeared feasible to extend this process to the fabrication of very large solid rocket motor cases. L. E. Zwissler, Aerojet-General Corp., in a paper entitled "Application of Shear Spinning to the Fabrication of Solid Propellant Rocket Cases", told the Conference how a development program was initiated to determine the feasibility of fabricating large-size component parts for assembly into full-scale chambers.

In the shear spinning process, a preformed blank is clamped between the tail stock of the shear spinning machine and a power driven spinning mandrel. The contour of the mandrel is the same as the inside surface of the finished part and the material is forced to flow onto the mandrel by the action of forming rolls. The shape of the preform must be developed in such a way as to obtain the desired metal thickness in the final product. The solution of this geometrical problem is complicated when the final form includes curvilinear elements such as those present in a semi-elliptical shaped head.

Small Scale Investigations – The parameters controlling the shear spinning process are affected by the material being spun; it is advantageous to investigate these in subscale units. The application described in Mr. Zwissler's paper was a large diameter chamber manufactured of A.S.M. 6434 alloy for operation at stress levels of 210,000 psi. minimum yield strength. The metallurgical condition of the material prior to shear spinning is important and interpass annealing was utilized to achieve total thickness reduction of 50 to 65% in two passes.

Inasmuch as the material is de-

(Continued on p. 169A)

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pioneers in pH cleaning control *serving you since '32*

Circle 1368 on Page 48-A

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furnace-furnace-quench-tanks (side-by-side) positioning

furnace-quench tanks-furnace (side-by-side) positioning

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Circle 1369 on Page 48-A

Metal Processing . . .

formed by flowing in shear by a significant amount, shear spinning is an effective self-inspecting process since existing defects are magnified and result in tearing the part. Because of the large deformations involved, some concern has been expressed over the possibilities of developing directional properties which would be undesirable in a highly stressed pressure vessel; however, metallurgical investigations of the material after spinning indicate that this is not the case.

(EDITOR'S NOTE — A report on papers presented at sessions on Metallurgical Problems in Electronics at the Golden Gate Metals Conference will be presented in an early issue of *Metal Progress*.)

Producing Iron Powder

Digest of "Iron Powder Produced by the H-Iron Process", by George G. Karian. Paper presented at the Philadelphia Regional Technical Meeting of American Iron and Steel Institute, Nov. 19, 1959.

THIS ARTICLE DESCRIBES the process in use by Alan Wood Steel Co. for producing iron powder directly from the ore. In a plant with a capacity of 50 tons per day, prepared iron ore is reduced by hydrogen gas at a temperature well under that required in a blast furnace.

High-grade magnetite from New Jersey is magnetically separated from the gangue and crushed to a fine particle size. The fine, relatively pure ore is then reacted with hydrogen gas at a temperature near 1000° F. at 500 psi. after the equation:

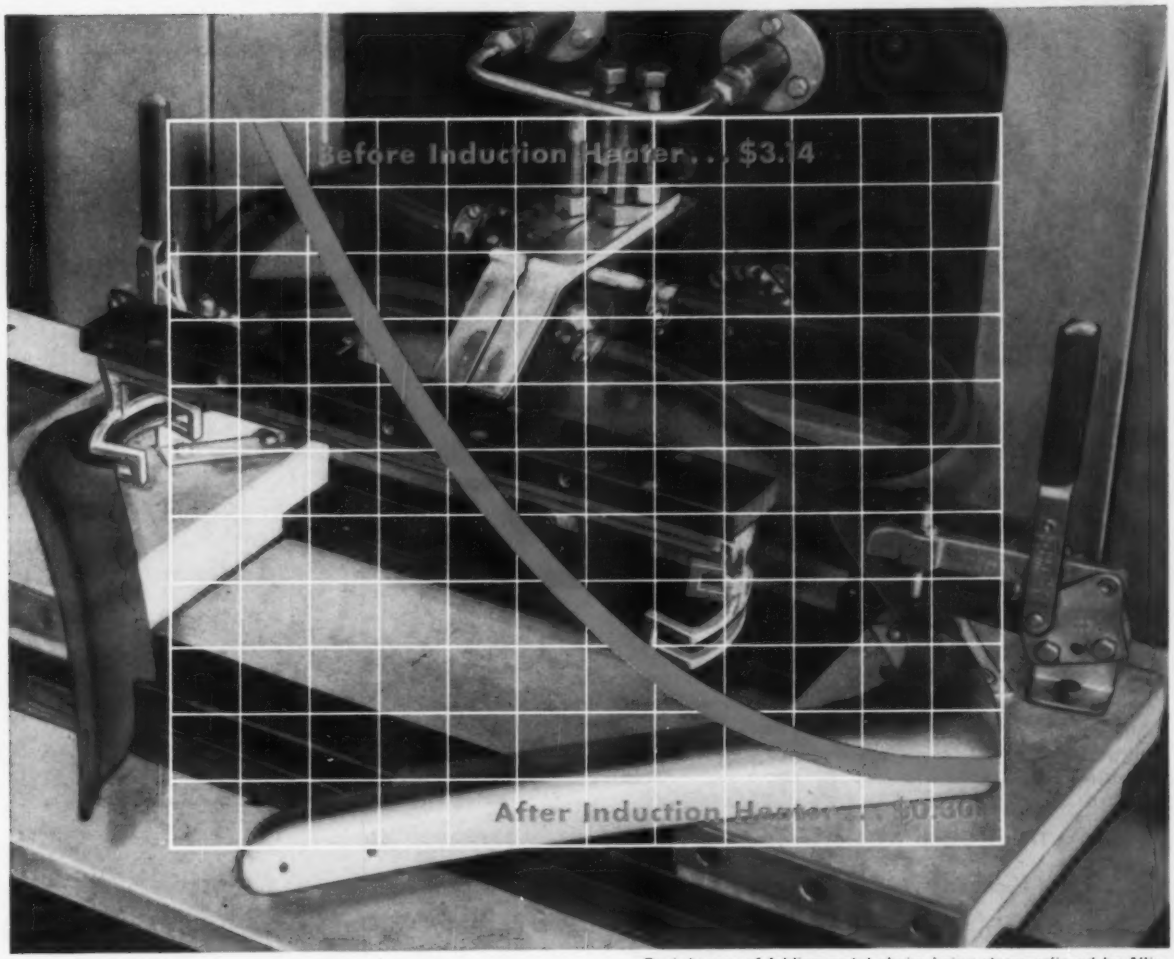
$$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$$

Since reduction of magnetite proceeds to nearly 98% (as compared with about 90% with hematite), magnetite is the preferred ore form.

Key to the success of the process is the high-pressure reduction using hydrogen and CO_2 gases that are a byproduct of coking operations. Nitrogen is readily available as a byproduct of the oxygen plant. All gases are recirculated for maximum efficiency.

Figure 1 illustrates the H-iron process. Prepared magnetite ore is valved into the charge hopper from the ore storage bin, and carbon

ALLIS-CHALMERS



Back braces of folding metal chairs being stress relieved by Allis-Chalmers induction heater. Two-position fixture speeds production.

Allis-Chalmers induction heater replaced oxyacetylene torch

heat costs dropped 90%

One of the Midwest's leading manufacturers of metal chairs and furniture switched to an Allis-Chalmers induction heater for stress relieving of strategic parts. One of his important savings was the cost of oxygen and acetylene. Costs had been about $3.14 per hour of operation. Electric power for the Allis-Chalmers induction heater costs about 30 cents.

In addition, he has been able to increase production from 247 pieces per hour to 422 pieces. Rejects have been greatly reduced. Die life is extended because induction heat leaves no appreciable scale.

The manufacturer has reported that savings made through use of the Allis-Chalmers unit paid the total cost of the heater in six months.

Such benefits as speed, economy and convenience make Allis-Chalmers induction heaters worth your consideration for any application needing soldering, annealing, melting, brazing, hardening or forging.

Allis-Chalmers excels in larger applications — induction heaters up to 150 kw have been applied to speed up production, save labor and improve product quality. In these larger applications Allis-Chalmers points to a significant number of installations.

• • •

Let us talk with you about possible applications. Call your A-C representative. Or write, ***Allis-Chalmers,*** *Industrial Equipment Division, Milwaukee 1, Wisconsin.* A-1302

Circle 1370 on Page 48-A

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Only the Tinius Olsen XY Electromatic U.T.M. puts the full versatility of an XY recorder at your fingertips. Using precision Olsen extensometers, specimen strain, even of fragile film, is measured and recorded in inches per inch—not assumed strain on a time basis. Uniform, consistently accurate and reproducible test results are assured—any time, anywhere with any Olsen testing machine.

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Testing and Balancing Machines
Circle 1371 on Page 48-A

Iron Powder . . .

dioxide is introduced to purge air from the charge hopper. A hydrogen stream, at 150 psi. over the pressure of gas in the reducer, transports the ore by dense-phase transport into the top bed of the reducer. Preceding the introduction of the ore into the first bed, the 98% reduced third bed iron powder is removed by dense-phase transport

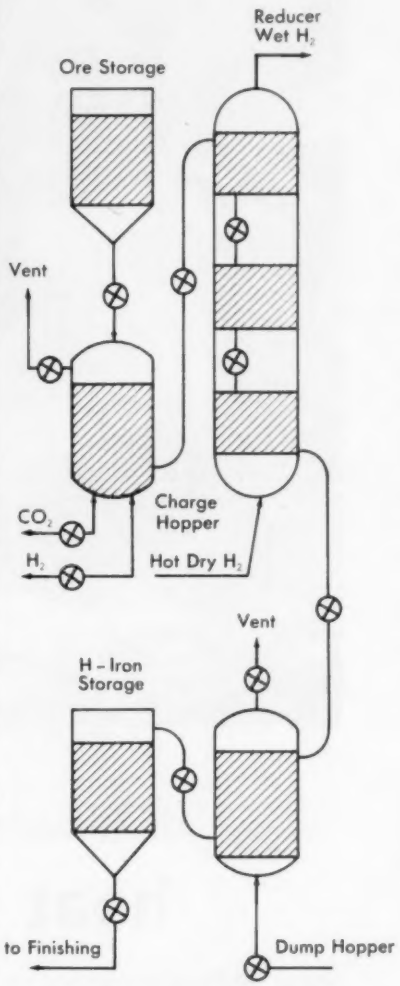
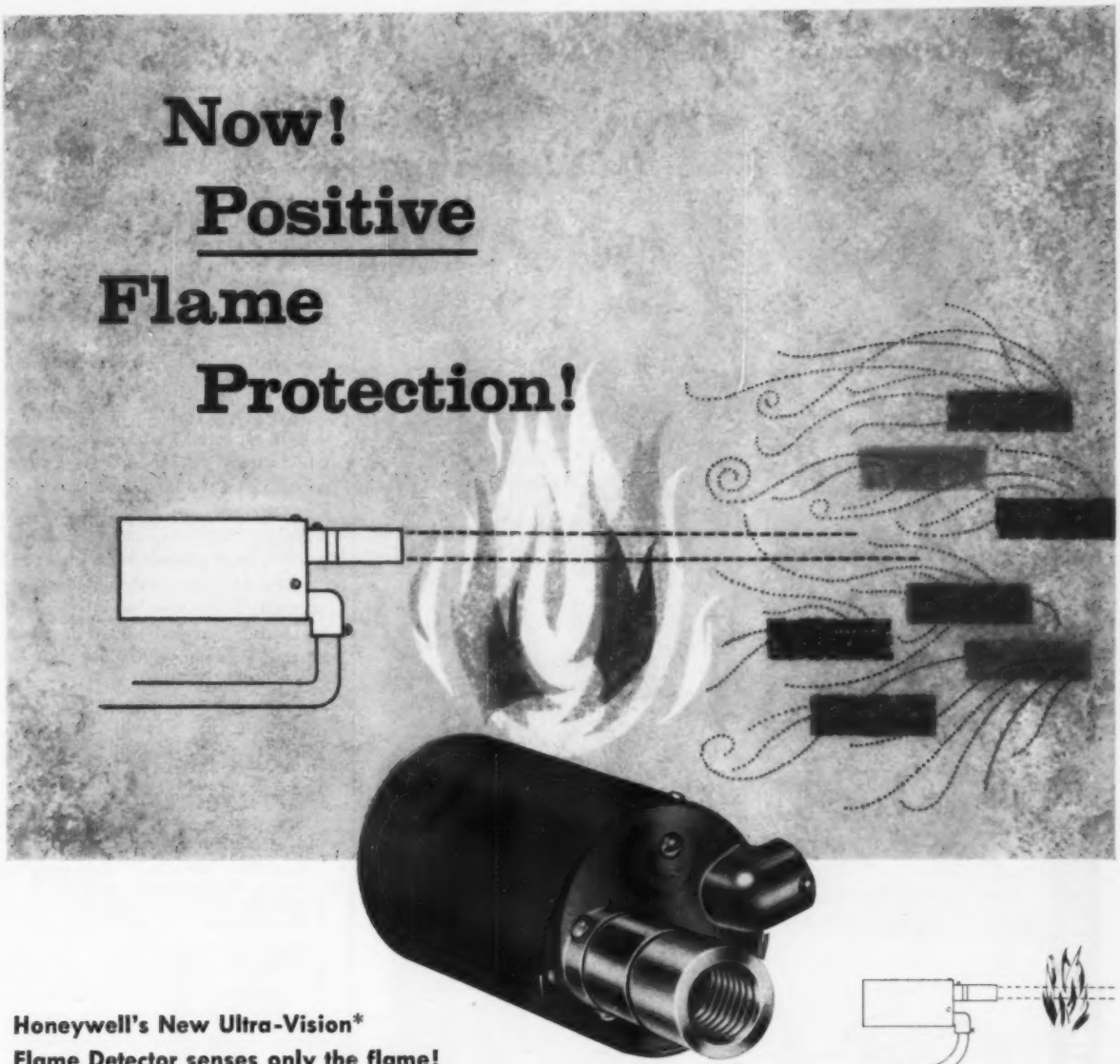


Fig. 1 – Diagram Illustrates H-Iron Process for Making Pure Iron Powder

to the dump hopper. The partly reduced ore in bed two is moved to bed three, while ore in bed one goes to bed two. During the transfer of ore from and within the reducer, the hydrogen flow remains at full pressure and passes in series from bed three to bed one. *(Cont. on p. 170)*

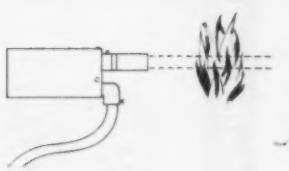
Now! Positive Flame Protection!



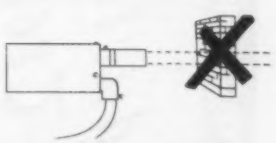
Honeywell's New Ultra-Vision* Flame Detector senses only the flame!

No more hot refractory hold-ins! This new Ultra-Vision Flame Detector responds to nothing but the ultraviolet energy given off by flame and sparks. It's the *only* visual flame detector that can tell the difference between real flame and red-hot refractory or glowing carbon. At last you can be *absolutely sure* that fuel delivery will be stopped in the absence of flame.

Only this compact new control simplifies flame supervision of both single and multiple burners. The Ultra-Vision Detector, not being sensitive to a hot refractory, can be aimed at each individual flame in the most convenient way. Actually pays for itself in simplified installation and maintenance. For all gas, oil and combination gas-oil installations. Get complete details from your nearby Honeywell field engineer. Call him today. Or, write for Bulletin 95-2776, Minneapolis-Honeywell, Minneapolis 8, Minnesota.



Ultra-Vision Flame Detector sights flame of all fuels.



Not affected in any way by a hot refractory or glowing carbon.

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Circle 1372 on Page 48-A

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Circle 1373 on Page 48-A

Iron Powder . . .

When the H-iron is transferred to the dump hopper, the hydrogen is purged with nitrogen. This nitrogen atmosphere is maintained in the storage hopper because the powder is pyrophoric until final processing.

The properties of H-iron powder make it adaptable to conventional powder metallurgy fabrication of structural parts, electrical parts and friction materials. H-iron powder can also be used for powder torch cutting and scarfing, and for coating some types of welding electrodes.

It is expected that H-iron powder will be used to produce steel sheet and strip by rolling and sintering. Pilot operations in this area indicate a highly satisfactory product can be made with great reduction in capital investment. An additional use is briquetted powder melting stock, pure or alloyed with added powders, for conventional melting operations.

W. L. BATTEN

Ultra-High-Pressure Techniques

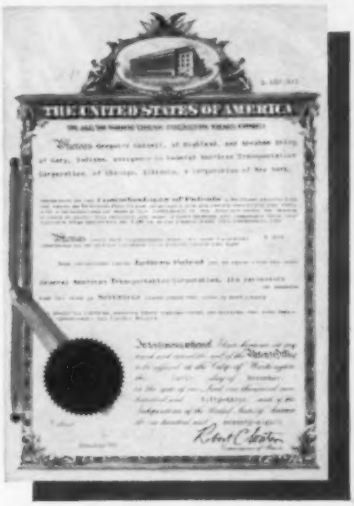
Digest of "Ultra High Pressure for Materials Research", by C. M. Schwartz and W. B. Wilson, *Battelle Technical Review*, June 1959, p. 3-8.

USUALLY, COMPOSITION and temperature are the variables employed in carrying out phase studies, whereas pressure is often neglected. It is common practice to use heat to supply the energy of an endothermic reaction or the activation energy which speeds up the rate of reaction. The phase rule suggests, however, that pressure, as another degree of freedom, may be capable of producing the new phases.

For instance, the effect of pressure on equilibria in gas systems, in which the volume change is appreciable, has been well established. Is there evidence, as well, of pressure effects on condensed systems, that is, on liquids or solids? Can we expect similar effects in liquids or solids, especially metals and inorganic compounds? On the whole, yes. The compressibility of solids, though small, is finite and measurable. We know, too, that with many elements and compounds which exist in two or

a Reminder

to those who use chemical nickel alloy plating:



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With Kanigen, you can plate anything from a small relief valve to a 20,000 gallon tank car with a virtually non-porous, uniform coating.

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Circle 1430 on Page 48-A

Ultra High Pressure . . .

more crystalline forms the high-temperature stable form is the more symmetrical structure, and consequently its atoms are most closely packed. Since increasing pressure favors the phase of higher density, it might be possible, if a high enough pressure were applied, to transform some solids into more dense forms not observed in nature. Pressure should, therefore, have an effect, not only on equilibrium conditions, but also on reaction rate.

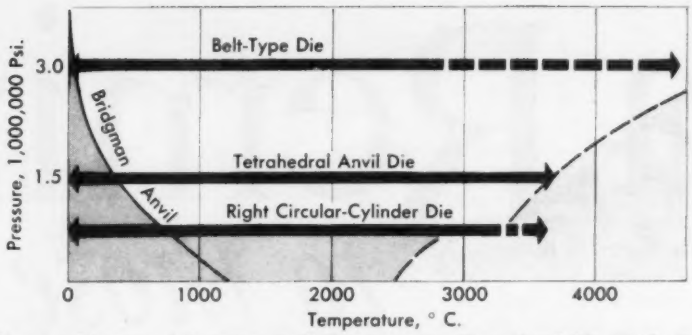

Fig. 1 — Ranges of Pressure and Temperature Now Available With Recently Developed Dies. The darkly shaded portions indicate the older ranges

What pressures might be needed to cause transformations in refractory solids? At a depth of only 250 miles below the surface, the pressure is greater than 1.5 million psi. To simulate geological processes in the laboratory, we should attain or exceed the latter value of pressure, and at elevated temperature.

Apparatus Needed

The simplest form of high-pressure apparatus capable of applying heat to the sample is the cylinder die and piston; they are usually made of cemented tungsten carbide. Though extremely strong in compression, the carbide must be protected from tensional stresses. Thus dies are incased in binding rings. The maximum pressure attainable, about 750,000 psi., is limited by the compressive strength of the unsupported piston, where it emerges from the die. Heat is applied internally by electrical resistance. The sample is incased in a thin-walled tubular resistor, which in turn, is incased in a close-fitting, thick-walled insulating cylinder of unfired Grade A lava. A bottom plug, insulated from the die, contacts the resistor tube, and current is passed through it and the resistor tube (and the specimen, if it is electrically conducting) to provide heating. Pressure capability can be raised to 1,500,000 psi. by incasing the entire die within a liquid-filled container under a hydrostatic pressure of 450,000 psi. This design is of limited value because heat is difficult to apply.

Another concept, that of massive support of the piston, is employed in Bridgman's "anvil" unit. In one example, two pistons of cemented car-

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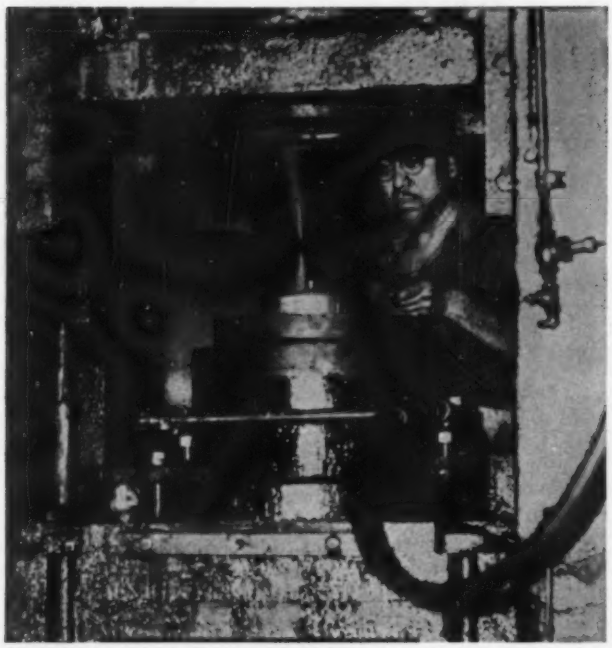
Circle 1375 on page 48-A

FORGING OR TAPPING . . . 'dag' DISPERSIONS BRING IMPRESSIVE SAVINGS

The versatility of Acheson 'dag' brand dispersions has been proven in many metalworking applications. Here are two such examples: the one involving the material-time savings possible by the use of sprayable colloidal graphite; the other, overcoming pressure and frictional heat problems with the use of a mica dispersion by Acheson.



'Prodag' is automatically spray-applied simultaneously on both upper and lower die surfaces of this forging press at Mueller Brass.

Mueller Brass Company saves $15,000 a year in labor-material costs alone. This is in addition to increasing die life, reducing the scrap loss, and improving the finish of their forgings . . . the reasons why Mueller initially chose Acheson's Prodag® over other forging lubricants. The total savings can be estimated as "considerable", since this Port Huron, Michigan company is the world's largest producer of brass and bronze forgings.

Before using 'Prodag' — a dispersion of graphite and water, Mueller lubricated their crank forging presses with a highly viscous, petroleum-based material which had to be swabbed by hand between each press stroke. The human element frequently meant too much lubricant being applied in some areas of the die, too little in others. The result in the first case, was either imperfect forgings or cracked dies brought about through displacement pressures. In die areas where there was insufficient lubrication, metal stuck in the die cavity. The forged piece had to be scrapped and time was lost while the metal was pried out of the die.

To overcome these multiple problems, Mueller was introduced to a sprayable lubricant and designed their own spray equipment, which lubricates lower and upper dies simultaneously. In this application, 'Prodag' is diluted 1 to 35 with water and is kept under agitation at the press. Time studies have shown that spraying has given them a five percent-per-pound economy over swabbing. Even more importantly, the use of 'Prodag' has resulted in more uniform, complete coverage. The $15,000 to $17,000 annual labor-material savings has, in Mueller's opinion, actually been a "bonus" over and above their original purpose of achieving better forgings and greater die life.

'dag' 242 improves hole tapping operation at General Steel Wares' Montreal Plant

Hole-tapping operations at General Steel Wares, Ltd., Montreal, Quebec, have improved with the application of 'dag' 242 — a dispersion of mica in petroleum oil. So much so, in fact, that an annual savings of approximately $8400 has been realized. The problem was this: broken spud threads during tapping operations on galvanized range boilers, caused a reject percentage of 27%. Fed to the tap as pictured below, the area of the boiler spud was subjected to high pressure and frictional heat. A proprietary type of water-soluble paste had previously been used.

Mr. E. R. Hails, Works Manager at General Steel Wares, found, after detailed investigation of all components involved in the operation, that the lubricant was the key to greater efficiency and fewer rejects. 'dag' 242 was recommended and put into use. Applied by brush to the tap and spuds, this material was immediately effective. The results speak for themselves; from an average life of 3000 spuds per tap, General Steel Wares now averages over 14,000 per tap with 'dag' 242.

Before threading range boiler holes, 'dag' 242 is applied by brush to the tap and spuds.

Perhaps you could be earning similar production economies by using one of the many fine Acheson Dispersions tailored for metalworking use. For further information write for your copy of Bulletin 426 — For Metalworking Applications. Address Dept. MP-40.

'dag', 'Prodag' are trademarks registered in the U. S. Patent Office by Acheson Industries, Inc.

ACHESON

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dag BRAND DISPERSIONS

ACHESON **ACHESON** *Colloids Company* **PORT HURON, MICHIGAN**

A division of Acheson Industries, Inc. Also Acheson Industries (Europe) Ltd. and affiliates, London, England

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Circle 1376 on Page 48-A

Ultra High Pressure . . .

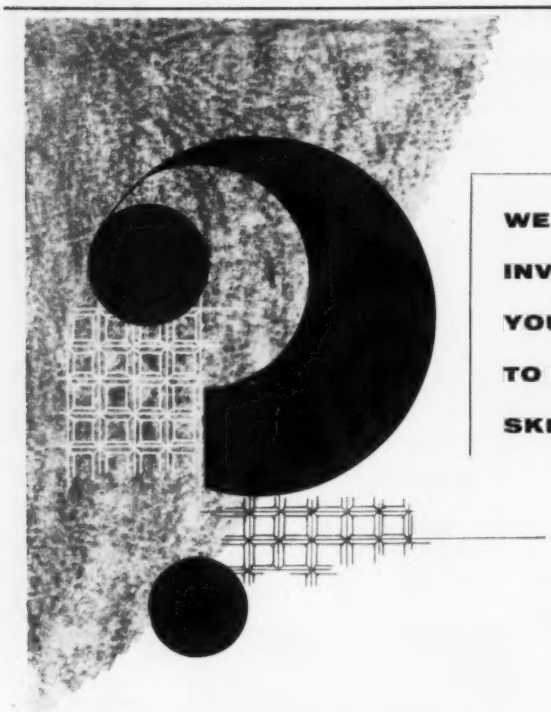
bide meet, with one or both working surfaces in the form of a flat truncated cone. The sample diameter and thus the area of the pressure zone is much less than that of the piston, so that binding-ring support is essentially provided over the entire length of piston. The sample, in the form of a thin disk about 10 mils thick, is placed within a gasket ring of talc-like pipestone. External heat is supplied from a tube furnace surrounding the pistons. Pressures to 3,000,000 psi. have been obtained with this apparatus, at room temperature.

A fully supported die, consisting of a compressed region in the shape of a regular tetrahedron (rather than cylinder or disk, as in other known designs), has been used. Four pistons of cemented carbide are constrained by hydraulic cylinders which move along lines perpendicular to the triangular faces of the tetrahedron. Piston faces are triangular anvils, and are beveled to nest together. Binding rings incase the carbide, to support the tensile forces which develop. This is called the "tetrahedral-anvil" apparatus.

Applications

The synthesis of diamond and the production of Borazon (BN), a material unknown in nature, are already well known. A number of other materials, most of them siliceous, have been synthesized in the laboratory. These include garnets, sillimanite, kyanite, and topaz. Ultra-high pressure can also be used as a research tool to improve our knowledge of solids and solid-state theory, but the way is neither paved or lighted. First, it will be necessary to study a large number of materials to establish a pattern for progress.

The application of ultra-pressure research to metallurgy offers attractive possibilities. The production of high-density phases of increased symmetry, the use of pressure to squeeze out voids, vacancies, dislocations, and other crystal imperfections, thus improving the mechanical properties of the material, are typical examples of the types of improvements to be expected in metal systems. C.R.W.



Charge components of the ferrous alloys we cast are measured frequently in split ounces. Molding sand is tested for properties every hour. Each heat, from each of the 6 electric furnaces, is laboratory tested — certain checks are made even *before* pouring is permitted.

Process control rigidly checks every step of production from receipt of raw materials through final inspection, assuring strict adherence to the tightest specifications — metallurgical, physical and dimensional.

Samples representative of every heat are subjected to chemical analysis. Castings for unusually critical applications often require specialized tests — partial or 100% X-ray inspection, ultra-sonic testing for internal defects, and others. These are provided.

Yet, with all these deterrents to speed, we have produced 150,000 castings a day — day after day.

If you need "prescription counter" accuracy in the make-up of your castings, we would appreciate an interview.

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OF NI-HARD, NI-RESIST,
DUCTILE IRON, AND
DUCTILE NI-RESIST

ENGINEERING CASTINGS, INC.

MARSHALL, MICHIGAN

Circle 1377 on Page 48-A

Oxygen for Basic Openhearths

Digest of "The Use of Oxygen Lances and Basic Brick in Open Hearth Roofs", by H. A. Parker and Philip Schane, Jr. Paper presented at Philadelphia Regional Technical Meeting of the American Iron and Steel Institute, Nov. 19, 1959.

THIS IS A VERY WELL WRITTEN, clearly outlined discussion of the development made in the use of oxygen in three of the openhearth departments of the United States Steel Corp. and also the results obtained in improved roof life and economics by the substitution of the fully suspended basic main roofs for the standard silica brick sprung design.

The basic roofs as developed are not only more economical in operation than the standard acid roofs, but permit the higher operating temperature which the oxygen lance develops so that the two developments in openhearth design and construc-

Copper Alloy Bulletin

BRIDGEPORT BRASS COMPANY

new BRIDGEPORT NIRONZE® 635 gives 90,000 psi yield strength

90,000 psi Yield Strength Obtained with New Age-Hardenable Copper-Nickel-Silicon Alloy

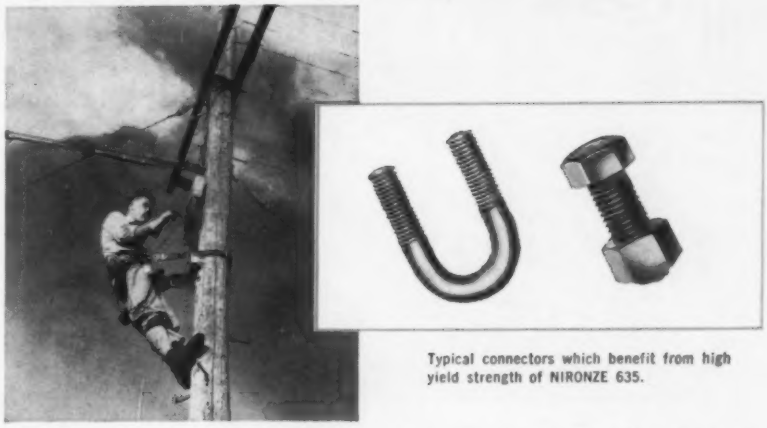
Bridgeport Nironze 635, an age-hardenable copper-nickel-silicon alloy, combines excellent cold-working properties with high tensile and very high yield strengths, good electrical conductivity, excellent general and stress-corrosion resistance. Supplied in the solution-treated and drawn condition, Nironze 635 offers exceptional cold-working properties. A low-temperature heat treatment, following additional cold-work age, hardens this alloy to produce tensile strengths of 100,000 psi, yield strengths of 85,000 psi and improved electrical conductivity of a minimum of 35% IACS.

Easily Cold-Formed ... Machined

The excellent cold-working properties of Nironze 635 in the *solution-treated and drawn* condition allow such severe cold work as upsetting, cold-heading, roll-threading, bending, forming or similar operations to be carried out with ease. Heat treatment following this cold-work age-hardens this alloy to produce maximum tensile and yield strengths.

Nironze 635 in the *solution-treated-drawn-aged* condition has a machinability about 30% of free-cutting brass rod, thereby making it possible to carry out such conventional machining operations as sawing, grinding, turning, milling or similar operations.

Maximum cold-work may be performed on Nironze 635 in the *solution-treated* or soft condition. In order to obtain highest possible physical properties, this alloy must be cold-worked from 50-80% before aging.



Typical connectors which benefit from high yield strength of NIRONZE 635.

Proved by Performance in These Applications

Cold-headed bolts and fasteners used in pole line hardware, switch gear, wire connectors, neon signs, railway equipment, exposed electrical parts and structural supports, marine hardware and fittings can all use Nironze 635 to advantage. The new alloy's unique combination of high yield and tensile strengths, good conductivity and high corrosion resistance provides design and production advantages never before offered by a silicon bronze.

Test a Sample Now

Nironze 635 has been thoroughly evaluated in the laboratory and in the field to insure the high quality and top performance common to all Bridgeport alloys. To get your test samples and full technical information, call your nearest Bridgeport Sales Office. Or write us direct. Dept. 4102.

Nironze 635 is presently available as rod or wire, supplied in the solution-treated, solution-treated and drawn, and solution-treated, drawn and aged.

NIRONZE PHYSICAL PROPERTIES

Density .....0.320 lb/in.³

Color Red.....similar to copper

Thermal Expansion.....8.9 x 10–⁶/°F

Melting Point .....1990°F

Electrical Conductivity
Cold-drawn and aged 30% min.
O/O IACS.....Cold-drawn 15% min.

MECHANICAL PROPERTIES (Nominal)

Form	Condition	Tensile Strength psi	Yield Strength psi	Elongation % (4D)	Contraction of Area %	Rockwell B Hardness	O/O IACS
Rod and Wire	Solution-Treated	40,000	12,000	50	90	7	24
	Solution-Treated, Aged	88,000	70,000	12	20	88	43
	S.T. Drawn 50%	65,000	62,000	18	87	67	22
	S.T. Drawn 50%, Aged	100,000	90,000	12	25	95	42
	S.T. Drawn 80%	70,000	65,000	15	85	73	22
	S.T. Drawn 80%, Aged	103,000	97,000	17	62	96	39

COMPARATIVE RATINGS OF NIRONZE 635 vs STANDARD SILICON BRONZES

	Physical Properties			Fabrication Properties			Mechanical Properties		
	Electrical Conductivity (Annealed) % IACS	Melting Point Liquidus °F	Density lb/in.³	Cold Workability	Machinability Rating %	Annealing Temp. °F	Tensile Strength psi	Yield Strength psi	Rockwell B Hardness
NIRONZE 635	*35	1990	0.320	Excellent	*30	**850-900	100,000	85,000	95
High Silicon Bronze (A)	7	1880	0.308	Excellent	30	900-1300	108,000	60,000	95
Low Silicon Bronze (B)	9	1940	0.316	Excellent	30	900-1250	90,000	67,000	90

The term "Nironze" is a registered trade-mark of the Bridgeport Brass Company

*Drawn and aged **Aging temperature

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Bridgeport 2, Connecticut • Sales Offices in Principal Cities
Specialists in Metals from Aluminum to Zirconium

Circle 1378 on Page 48-A

Chace
THERMOSTATIC BIMETAL
Actuates Another Precision Product

THE WESTINGHOUSE ELECTRIC BLANKET CONTROL

A PRODUCT OF
WESTINGHOUSE ELECTRIC CORPORATION
MANSFIELD, OHIO

This new control for the Westinghouse "Aristocrat" Electric Blanket provides cozy, gentle warmth regardless of weather conditions or changes in room temperature. You simply set the Control Dial to the warmth desired and the blanket automatically maintains the comfort range selected, all night long. Twin, double with single or dual controls, or King size types are available. The signal light is a reminder that the Control is on. The protective thermostats are actuated by nine Chace bimetal elements for positive protection against overheating. They are accurately calibrated and sealed against moisture.

Chace is always eager to accept the burden of proof of the quality of the thermostatic bimetal we manufacture and we suggest that millions of reliable appliances working day and night without care or worry are the soundest kind of proof. In this instance, we assume a multiple responsibility as each position on the Control Dial is really a separate thermostat in itself, hence the necessity for precision and dependability is multiplied. Chace customers through the years have learned that their precision products can be sent out safely to their buyers in industry and the home when Chace furnishes the actuating bimetal; and new manufacturers who look at our record of a third of a century of development and production of precision thermostatic bimetal exclusively soon acquire a similar confidence in Chace.

When your new temperature-actuated device approaches the design stage, send for our booklet, "Successful Applications of Chace Thermostatic Bimetal", containing valuable engineering information. Remember, too, that over 30 types of Chace Thermostatic Bimetal are available in strip, coils or completely fabricated elements of customer's designs.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1626 BEARD AVE., DETROIT 9, MICH.

Circle 1379 on Page 48-A

Basic Openhearths . . .

tion are mutually dependent. This higher operating temperature is the basis on which the increase in production actually depends. It is shown that there is a direct, straight-line relation between size of carbon steel heats and tons per hour produced if sufficient oxygen is used in a properly designed lance. Very complete data are given of runs made in three plants of small, medium and large openhearth furnaces indicating that the basic roof with high-pressure water cooled oxygen jets will soon become a standard in this part of the steel industry. The figures given are sound and should serve as an excellent guide to anyone interested in getting the best tonnage results from oxygen in a steel melting furnace making low-carbon steel.

The section on suspended basic roof construction is also very clear, and should make good reading for every openhearth operator, whether he is using oxygen or not. This is especially true of the conclusion that allowance for expansion could be eliminated. H. W. McQUAID

Welding Pipe in Russia

Digest of "Electric Resistance Welding of Line Pipe", *Svarochnoe Proizvodstvo (Welding Production)* No. 2, 1959.

OVER 30,000 MILES of pipe line, including 16,000 miles of gas pipe, 28 to 40 in. in diameter, is scheduled to be installed in the U.S.S.R. during the 1959-1965 period. The E. A. Paton Welding Institute in cooperation with the U.S.S.R. Gas Institute has been developing mechanized methods of pipe welding, one of the most promising of which is flash butt welding. This method permits continuous production of pipe of indefinite length, as well as 100% mechanization of all setup, fitting and welding operations.

Resistance flash butt welding has been widely used for items of small cross-sectional area. It is well known that welding of large diameter cross sections (tubing, sheet) presents many difficulties. These difficulties have been eliminated by the development of the so-called contour transformers for butt welding. One of these is a "ring" transformer, whose

thermal thicket

Problem: *The heat barrier which now hinders hypersonic aircraft and missiles.*

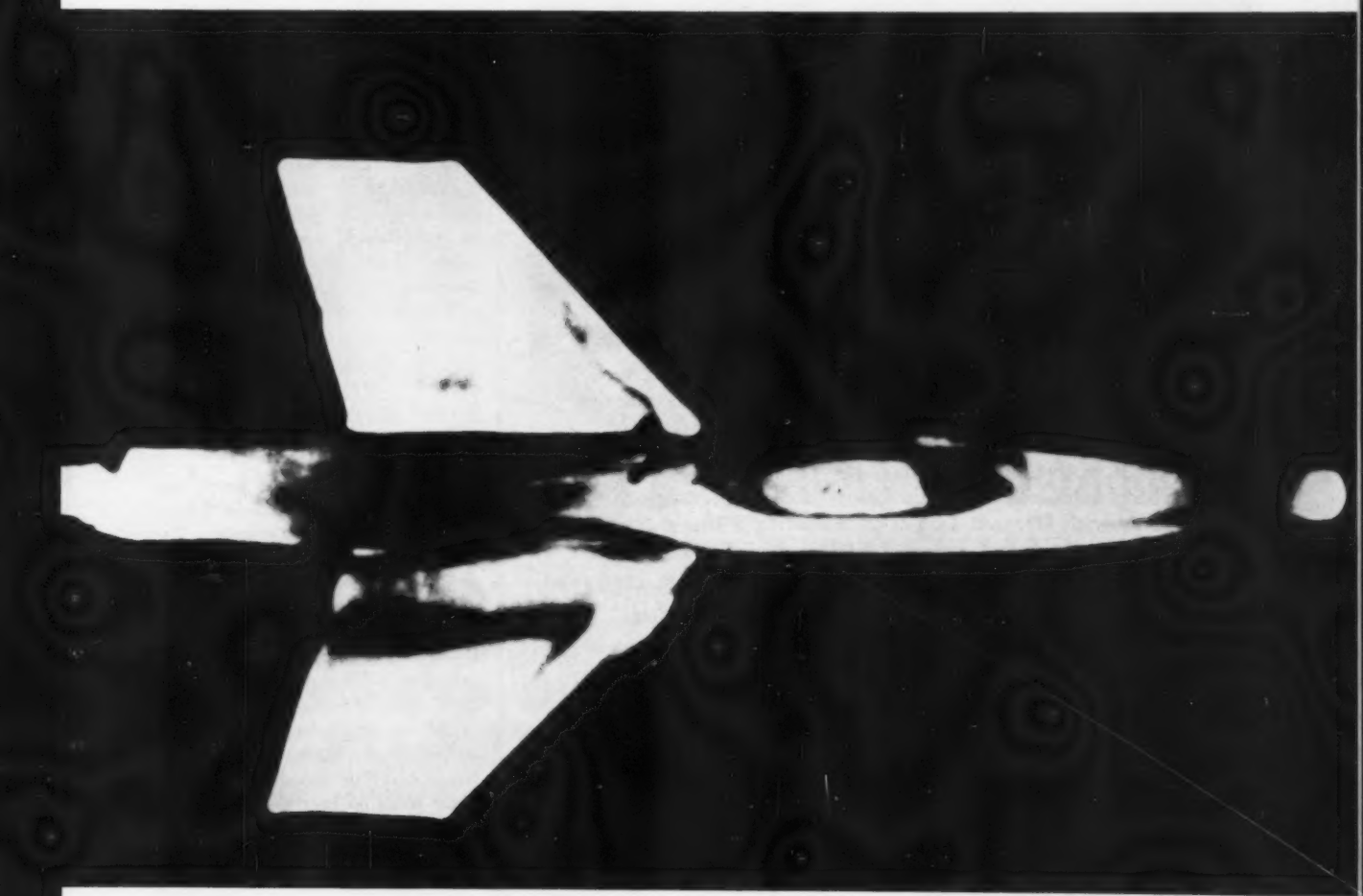
Needed: *Dependable high temperature alloys for structural components.*

Solution: *Find the right alloys that are easy to forge and machine and are truly uniform.*

Source: *Predictable performance Carpenter alloys made by the exclusive Mel-Trol, VacuMeltrol and Consumet melting processes.*

Engine builders find them ideal for many critical parts. Forge shops report improved forgeability resulting in better finishes requiring far less machining. Work goes faster. Rejects are fewer.

Call your local Carpenter Representative for the whole story about predictable performance alloys and how they can benefit you. The Carpenter Steel Company, Reading, Pa.



a new company 70 years old

Carpenter steel

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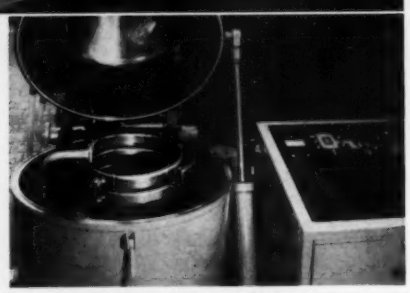
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

Circle 1380 on Page 48-A

Sinter in Vacuum up to 3,000° C!



Water-cooled, wear-free induction coils produce electro-magnetic field for fast, uniform heating.

Centigrade, notice, not Fahrenheit. This temperature has many times been achieved, and maintained, under laboratory conditions with Heraeus Induction Sintering Furnaces. In production, temperature range of 2,600°C to 3,000°C is typical.

More significant, these Heraeus furnaces improve end product quality while cutting operating costs. You get uniform heat distribution . . . faster heating . . . and longer element life . . . than with any other vacuum furnace on the market today.

There's a complete line to meet your needs, with coil diameters from 6¾" to 20½" . . . with choice of pumping systems for working pressures from atmosphere down to the 10^{-5} range. Each gives you complete facilities for the widest range of vacuum metallurgy: sintering, reactive work, degassing, purification of metal powders, brazing, annealing, hardening. Each saves the high cost of constantly replacing the expensive elements required in resistance heating.

Find out more about higher quality work, lower operating costs. Write for Bulletin 4-25.

Consolidated Vacuum Corporation

ROCHESTER 3, NEW YORK

Circle 1381 on Page 48-A

Welding Pipe . . .

core is designed as a ring clamping the welded pipe. Primary coils and sections of the secondary loop are uniformly distributed over the core. Due to the features of the design of the secondary circuit, and its small size, resistance of the short circuit of the welding machine with the ring transformer is many times smaller than the short circuit resistance of a conventional large-capacity machine. Because of this, as well as the perfectly symmetrical current supply to the welded pipe, the ring transformer produces high quality welds with very low power input.

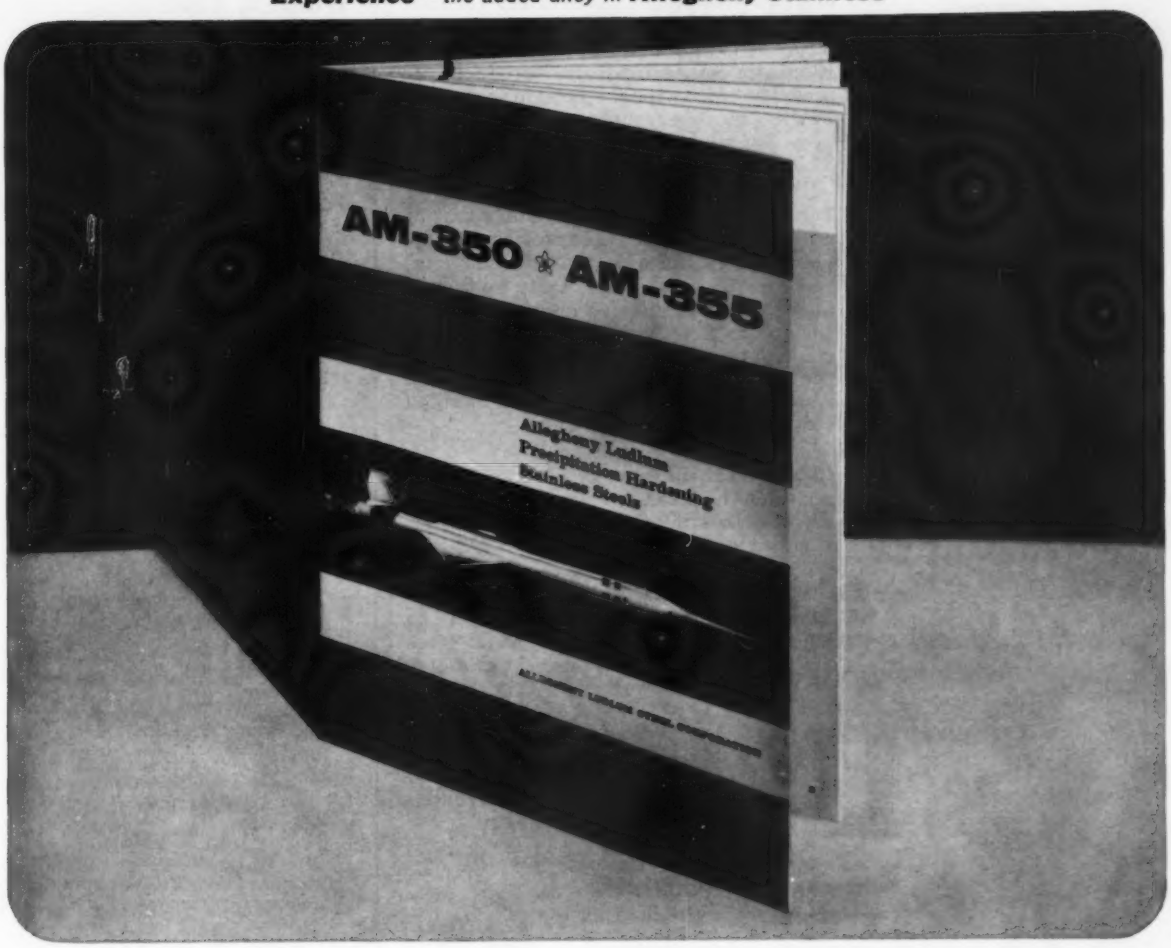
Ring transformers permit field welding of large diameter pipe through special installations developed by the Paton Institute. The installation consists of a welding head, special tractor, power supply, tool for the removal of fins, and a tool for cleaning the pipe surface for contact with the welder. Assembly alignment and welding is done in the welding head, which consists of two hinged halves which open upon raising of the head and close upon lowering.

Two drives draw the abutting surfaces together. During fusion, a d-c. driven electromechanical drive regulates the melting rate. The butt is upset by a four-cylinder, double-acting hydraulic drive at about 1 in. per sec.

The welding head and power supply are transported from one butt to the next by a special tractor. Fins are removed while still hot immediately after upsetting. At the same time, the inside diameter butt weld reinforcements are partially removed. Resistance welding has been used in pipe line welding since 1952. About 1200 miles of oil and gas pipe, 8½ to 21 in. in diameter, have been welded by this method. Experience has shown that one welder can produce 50 to 60 butt welds per shift, and in 1958 some installations achieved production of 100 to 120 welds per shift.

For example, cost per mile of the Omsk-Novosibirsk pipe line was 2.5 times less than that of a similar line welded by the automatic submerged arc method. It has been estimated that the flash butt welding of 600 miles of 21 in. pipe saves 5 million rubles compared with submerged flux

Experience**—the added alloy in **Allegheny Stainless



New booklet on A-L's precipitation-hardening stainless steels, AM-350 and AM-355

A tool for anyone interested in high strength-to-weight metals

In this technical booklet, you get the facts on Allegheny Ludlum's precipitation hardening stainless steels, AM-350 and AM-355, metals developed for space age requirements.

AM-350 and AM-355 combine these unusual qualities. They are easy to fabricate. Have high strength-to-weight ratios at room and elevated temperatures combined with excellent resistance to corrosion.

The physical and mechanical properties of the two metals are described in 33 charts and tables. Included are heat-treatment and fabrication data, eight photomicrographs and a section on corrosion resistance with representative values in selected environments.

It's jam-packed with data. For your free copy, see your A-L representative or write *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa. Address Dept. SHN-3.*

955

ALLEGHENY LUDLUM

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

Circle 1382 on Page 48-A

Discharge Valve

SWITCH FROM SAND CASTINGS TO BRASS FORGED PARTS

Here's why! Your component parts forged of Titan brass will outperform any you now buy as sand castings. No more costly rejects due to blow holes and sand inclusions. Eliminate leakage and other product failures. The twice-wrought metal in brass forgings has the inner toughness and density to give you new strength and workability. Thinner sections can be used.

Tensile strength is almost double that of most sand castings. Closer tolerances, dimensional uniformity of production lots, and superior finish unknown in sand castings are routine in Titan forgings. For you this means faster chucking and better machinability—threads can often be chased on the forging without preliminary forming. And you have less scrap and less finishing cost prior to plating.

In a Titan forged part you get greater eye appeal to help sell your product. Look at the smooth surface of these forgings to see what we mean; each was once a rough sand-cast part.

May we say more? Call your nearest Titan office for detailed information and a brass forging quote on your sand-cast parts.

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Main Valve Control

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Main Valve Seat

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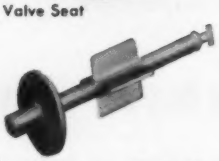

Lavatory Pop-up Plug

Circle 1383 on Page 48-A

Welding Pipe . . .

welding. This is achieved by reduction of labor for transportation, easier welding setup and reduced cost of welding lubricants. It is planned to use resistance flash butt welding for 60% of all 21 in. diameter pipe lines installed in 1960.

A. B. TESMEN

Shot-Peening and Grinding

Digest of "The Effect of Shot-Peening and of Grinding on the Fatigue Strength of Chromium Plated High Strength Steel", by C. Williams and R.A.F. Hammond. Paper presented at Golden Jubilee Convention, American Electroplaters' Society, Detroit, June 1959.

IT HAS BEEN KNOWN for some time that the fatigue strength of a constructional steel is reduced by chromium plating. The percentage reduction increases with the ultimate tensile strength, and may be as high as 60% for a steel whose tensile strength is about 220,000 psi. High-strength steels such as this have to be baked at a low temperature after plating to eliminate hydrogen embrittlement without softening the steel or the plate, but this treatment has been found to reduce the fatigue strength even more.

Shot-peening of low-strength steel prior to chromium plating can eliminate the drop in the fatigue limit that would otherwise result. The work described in this paper was undertaken to determine whether shot-peening would have the same beneficial effect for high-strength steels, particularly when baked at a low temperature after plating. In addition, studies were made of the effects of grinding either the shot-peened steel or the chromium deposit, since such grinding is often necessary from the standpoint of a satisfactory surface finish. Surface rolling prior to plating was investigated briefly.

A 2.5% Ni steel, heat treated to 180,000 psi. tensile strength, and a 4340 steel (224,000 psi.) were fatigue tested in the form of 0.3 in. diameter rotating-bending specimens that had been processed by various combinations of methods involving electropolishing, shot-peening, grind-

(Continued on page 192)

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Crobaugh Laboratories uses new X-Ray Spectrometer and conventional methods to get accuracy from 1 p.p.m. range to 100%.

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Flame Hardening does not require furnaces

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Let us help you—from design to completed machine

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We can flame harden anything that can be shipped over the highway or on a freight car

Write for either or both of these beautifully illustrated catalogs "Flame Hardened Rolls" or "Flame Hardened Machine Ways," each includes charts and valuable data.

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Now . . . Solder Aluminum with ordinary soft solders

- Use 60-40, 50-50, 40-60, 95-5 solders
- No new soldering techniques
- Non-acid . . . Self-cleaning

A major breakthrough in aluminum fabrication. Use ordinary soft solders . . . ordinary irons or torches. Remarkable fluxing action achieves perfect bond of aluminum and solder making possible the fabrication of aluminum to aluminum, copper, steel, stainless steel, galvanized iron, brass, etc.

Write for sample, or engineering help on any fluxing problem.

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Silver Solder Flux

Greater speed and economy for all silver soldering!

- Packed in tins
- Will not harden
- Non-acid . . . Self-cleaning

For all silver soldering in 1125° to 1700° F. heat range. Dissolves all refractory and non-refractory oxides . . . solder penetrates completely into all areas, for maximum strength without solder waste. Completely acid-free—will not pit or stain metals. Always-ready paste form . . . will not harden or crystallize.

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Stainless Steel & Chrome Soldering Flux

Safer . . . Surer . . . Cleaner

- Doesn't stain
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For soldering all stainless steel and chrome, including 300-400 Series, with ordinary soft solders. Requires no pre-cleaning. Acid-free formulation will not pit metals, leaves no stains. No buckling on even light gauge work. In liquid or paste form.

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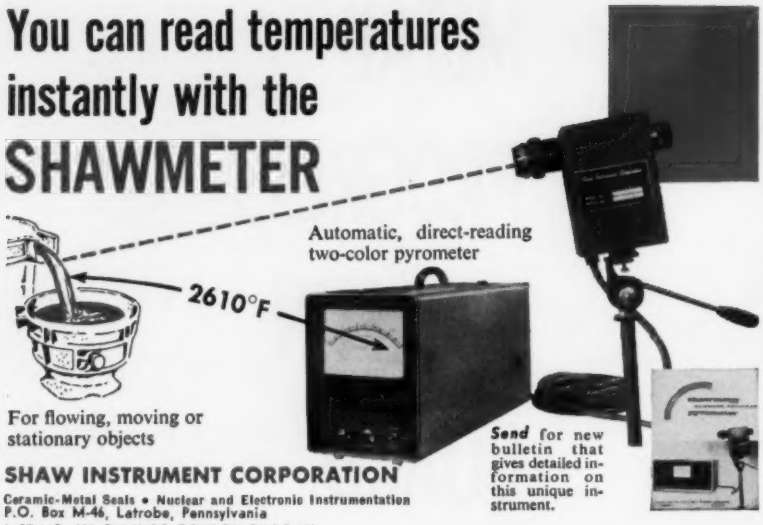
You can read temperatures instantly with the SHAWMETER



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"Eliminate chance" in hiring and assignment of personnel to jobs. Save by reducing rejects — rework. Instant reading — highly accurate and foolproof. •Literature

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Multi-Purpose Fatigue Testing Machines for Research and Production

push-pull, bending, torsion tests, on hard and soft materials. Infinitely variable speed—extremely large stroke—additional low speed drive.

Built-in controls maintain constant static and dynamic load.

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Spotcheck offers

- NEW! NONFLAMMABLE
- PUSH-BUTTON EASE
- FLEXIBILITY . . . Use on tools, parts, machinery, etc.
- LOWEST COST Dye Penetrant materials — pressure canned or bulk. Why use higher priced substitutes?

COMPLETE SK-3 KIT ONLY
$36.00 U. S. A. only
Plus $1 for packing and shipping

CALL YOUR DISTRIBUTOR or Mail Check or P. O. with Coupon Today!

MAGNAFLUX CORPORATION
7328 W. Ainslie Ave., Chicago 31, Illinois

☐ Please send____SK-3 kits @ $36.00 each plus $1.00 each packing and shipping.

☐ Send FREE bulletin only. Includes low SPOTCHECK material prices.

Name_____Title_____
Company_____
Address_____
City_____Zone____State_____

LIST NO. 198 ON INFO-COUPON PAGE 190

Leitz MINILOAD TESTER

FOR VICKERS AND KNOOP HARDNESS

STANDARD HARDNESS TESTERS for ROCKWELL and BRINELL TESTS also available.

Request Catalog 72-1

OPTO-METRIC TOOLS, INC.
137 MP VARICK STREET, NEW YORK 13.

LIST NO. 162 ON INFO-COUPON PAGE 190

SUB-ZERO

low temperature equipment

for

- shrink fits
- seasoning gauges
- precision tools
- laboratory testing

1.5 and 6.5 cu. ft. capacities. Sturdy, all-steel cabinet construction. Sublids for constant inside temperature. Adjustable temperature controls. Special accessories available.

For more information— Write to:

Revco INC.
Deerfield, Michigan
Specialists in Trend-Setting Refrigeration

LIST NO. 200 ON INFO-COUPON PAGE 190

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revolutionary • low cost

Newage MICROHARDNESS TESTER

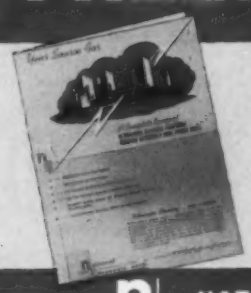
- permits direct, accurate readings corresponding to Vickers within a few seconds
- ideally suited for on-the-job production work
- eliminates a microscope, conversion charts, complicated tables
- for rapid and accurate checking of surface layers, thin sheets, flat springs, instrument parts, wire punches, etc.
- can be obtained in 1 kg or 2 kg loads penetrating as little as .000079" or .00016" respectively

NEWAGE INDUSTRIES, INC.
222 YORK ROAD
JENKINTOWN 5, PA.
TUrner 4-8494

Write, wire or call for full details

LIST NO. 207 ON INFO-COUPON PAGE 190

FREE! ULTRASONIC CLEANING BULLETIN



Describes National Ultrasonic Corporation's:

- Applications Laboratory service. Your sample parts are cleaned ultrasonically and equipment and cost recommendations are made at no charge.
- STANDARDLINE medium power cleaners for all applications requiring average energy levels.
- HEAVYDUTYLINE high power cleaners for industrial applications requiring high energy density.
- NUclean® solvents and detergents especially formulated for ultrasonic cleaning.

NATIONAL ULTRASONIC CORP.

111 Montgomery Ave., Irvington 11, N. J.
ESsex 1-0550 • TWX NK 1030

LIST NO. 240 ON INFO-COUPON PAGE 190

Rockwell-scaled
HARDNESS TESTER

REVOLUTIONARY—NEW-"ON-THE-JOB" *Precision Instrument*

only $39.50 *complete!*

A steel ball of exact weight and hardness is dropped from an exact height, insuring a precise reading in Rockwell C scale. Ideal for spot or production checking. Portable, easy to read . . . rugged and dependable. In use in many large plants and shops.

Order yours today at this low price. Satisfaction guaranteed.

DETROIT HARDNESS TESTER

17644 Mt. Elliott Ave.
Detroit 12, Mich.

pat. app. for

LIST NO. 247 ON INFO-COUPON PAGE 190

TENSILKUT®

Pat. Pend., U.S., Canada

● Now with TENSILKUT, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . . from .0005" foil to .500" plate. Hard .001 stainless steel foil to soft ½" aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates in .500" plate, are machined with specimen configurations accurate to ± .0005". Machined edges are completely free of cold working or heat distortion and require no hand finishing.

● TENSILKUT table and floor models are available with motors from ½ to 2½ h.p. Write for free brochure.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut

LIST NO. 131 ON INFO-COUPON PAGE 190

THE NEW
DERMITRON
NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST . . . ACCURATE NON-DESTRUCTIVE DIRECT-READING

- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
- Enables measurements on small or otherwise inaccessible areas

This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

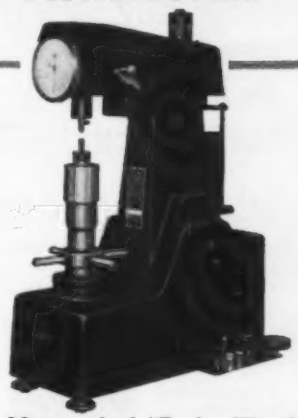
- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
- Non-metallic coatings (such as paint, anodizing, hard-coat, ceramic) on metal base
- Metal films (such as vacuum metalizing) on non-metallic base (plastics, ceramics)

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

LIST NO. 139 ON INFO-COUPON PAGE 190

Wilson "Rockwell" TWINTESTER



- Measures both "Rockwell" and "Rockwell" Superficial hardness on B, C, N, T and other scales
- Easy to operate—change from "Rockwell" to "Rockwell" superficial testing in seconds
- Large direct-reading dial with one zero set position for all scales
- Complete equipment includes cowl, ball penetrator for B and T scale, "Rockwell" test blocks, anvils, dust cover, and protective sleeve set
- Complete line of accessories available

Write to Dept. DU. Ask for Bulletin TT-59

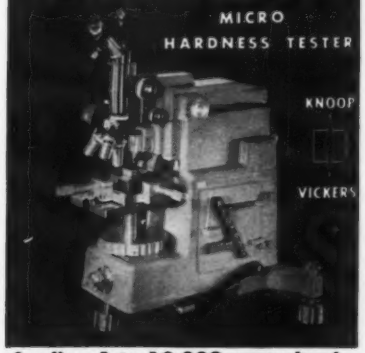
WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division ACCO

American Chain & Cable Company, Inc.
230-F Park Avenue, New York 17, N.Y.

LIST NO. 209 ON INFO-COUPON PAGE 190

KENTRON
MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

Write for Bulletin

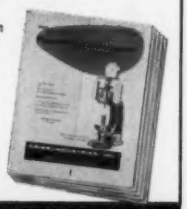
Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

LIST NO. 53 ON INFO-COUPON PAGE 190

the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus 2½ kg



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GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

LIST NO. 135 ON INFO-COUPON PAGE 190

Now find cracks, leaks, defects . . . *quickly, easily!*

ZYGLO

BLACK LIGHT Portable Inspection Kit

Easy to Use
- in the shop
- in the field

FLUORESCENT PENETRANT INSPECTION

"IDEAL FOR"
- Low-volume production testing
- Maintenance and tool inspection
- Reliable leak test —welded tanks

FIRE SAFE
New, improved high flash-point materials. Packed in push-button spray cans.

Genuine ZYGLO KIT complete with 100 W. BLACK LIGHT
$125.00
F.O.B. Chicago

MAGNAFLUX CORPORATION
7328 West Ainslie Avenue
Chicago 31, Illinois

LIST NO. 248 ON INFO-COUPON PAGE 190

Solve Inspection Sorting Demagnetizing *Problems*

with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT
Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

MULTI & SINGLE FREQUENCY EQUIPMENT
Eddy current equipment for non-destructive testing of non-magnetic metal tubing, bars, wire, ⅛" to 3" dia. at test speeds from 200 to 600 fpm. Multi-frequency unit offers 6 simultaneous inspection methods to indicate surface and subsurface flaws, or variations in mechanical, physical, and metallurgical properties. The single frequency unit offers one inspection method to indicate flaws only.

WIRE ROPE EQUIPMENT
Electronic equipment for inspecting ferromagnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS
Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS
Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETISM DETECTORS
Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"

For Details Write:
MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

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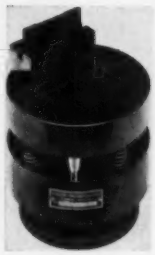
MULTI MOTION DIES* ....
FOR COMPACTING POWDERED MATERIAL TEST SPECIMENS ....



DL-1001
TENSILE TEST BAR
MPA STANDARD
10-50

- Tensile Bars
- Transverse Bars
- Green Strength
- Bushings
- Slugs
- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

*PATENTED

HALLER, INCORPORATED
16580 Northville Rd., Northville, Mich.

LIST NO. 149 ON INFO-COUPON PAGE 190

make hardness tests
ANYWHERE
WITH THE
NEWAGE TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

NEWAGE INDUSTRIES, INC.
222 York Road, Jenkintown 6, Pennsylvania
TUrner 4-8494 Dept. MP

LIST NO. 163 ON INFO-COUPON PAGE 190

HARDNESS TESTING SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.

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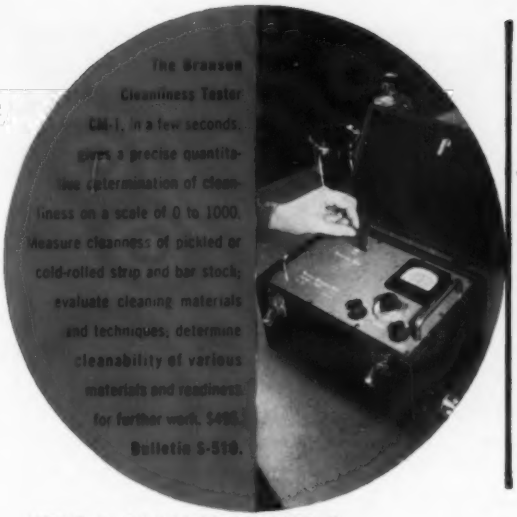
The Branson Cleanliness Tester CM-1, in a few seconds, gives a precise quantitative determination of cleanliness on a scale of 0 to 1000. Measure cleanness of pickled or cold-rolled strip and bar stock; evaluate cleaning materials and techniques; determine cleanability of various materials and readiness for further work. $400. Bulletin S-510.

DO YOU KNOW...

HOW CLEAN IS CLEAN?

BRANSON ULTRASONIC CORPORATION
6 Brown House Rd., Stamford, Conn.

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RUST-LICK
IN
AQUEOUS SYSTEMS

Eliminates RUST
&
Fire Hazards
Non-Flammable
Non-Toxic

Send for Brochure:
The ABC of Rust-Lick for Rust Prevention

RUST-LICK, INCORPORATED
755 BOYLSTON STREET
BOSTON 16, MASS

LIST NO. 105 ON INFO-COUPON PAGE 190

RAMCO
modular power spray washers

☑ MAXIMUM PERFORMANCE
☑ MAXIMUM ECONOMY

Proof? In this Ramco Bulletin . . . shows how you can create the *right* system for today's . . . and tomorrow's needs. *Send for your copy* NOW! Ask for Bulletin 659-1.

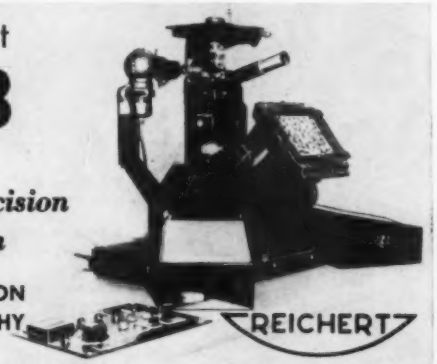
RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd. New York 39, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 190

Reichert
MEFLAB

inexpensive precision metallograph

VISUAL OBSERVATION
PHOTOMICROGRAPHY
PROJECTION



Nearly a Century of research produced this Brilliant Optical System.
For further particulars or a demonstration contact
WILLIAM J. HACKER & CO., INC.
Box 646, West Caldwell, N. J.

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Another
PRODUCT
of
TECHNIC
Research

BROTHERM H+

HEAT RESISTANT 24K Acid Bright GOLD

HEAT RESISTANCE
...5 Hours 400°c Minim
TEMPERATURE RANGE
...65°f to 115°f
HARDNESS...150+ Knoop
Mirror Brightness
One addition agent
Barrel or Tank Operation

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Technic inc
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Providence, R. I.
STuart 1-6100
PRODUCTS OF RESEARCH
Chicago Office
7001 North Clark Street

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Impervite

Corrosion-Proof EQUIPMENT

. . . manufactured from impervious graphite by Falls Industries, Inc., the leading developer of new and improved graphite equipment for the processing industries. Catalogs available on request.

FI THERMOWELLS

Immune to thermal shock — minimum lag time — three standard designs available from stock. Bulletin 1145.

PARALLEL EXCHANGERS FI

Another exclusive development for inexpensive low volume heating or cooling. Heat transfer section is single piece of impervious graphite, without joints. Bulletin 1205.

FI CRUCIBLES

Made of "pure" graphite without clay or other filler (NOT IMPERMEABLE). Standard sizes to 30" O.D. Specials to 48" O.D. Bulletin 1020.

PLATE HEATERS FI

Four styles, virtually unlimited range of sizes. High rate of thermal conductivity (prox. 10 times that of stainless steel), immune to thermal shock. Bulletin 753.

FI CROSS-BORE EXCHANGERS

An exclusive development utilizing a "one-piece", heavy duty, heat transfer cylinder. Furnished to 240 sq. feet of transfer surface. Larger capacities on order. Bulletin 660.

BAYONET HEATERS FI

Four sizes for heating or cooling limited quantities of gases or liquids. Bulletin 753-2.

OTHER *Impervite* EQUIPMENT

	BULL. NO.		BULL. NO.
Cubical Exchangers	182	Centrifugal Pumps	854
Tube & Shell Exchangers	448	Control Valves	.....
Modular Exchangers	279	Process Valves	.....
Cascade Coolers	537	Pipe & Fittings	790
Towers	505	Rupture Disks	315

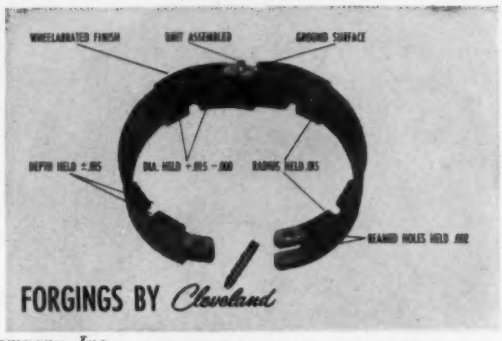
FALLS FI INDUSTRIES, INC.
31912 Aurora Road • Solon, Ohio

LIST NO. 249 ON INFO-COUPON PAGE 190

PRINT-TO-PRODUCT SERVICE

How many of these steps does your product need?

If you can use skills and close tolerances like these, write for information to *Forge & Fittings Division, H. K. Porter Company, Inc., Cleveland 4, Ohio*



FROM A SINGLE SOURCE:

FORGINGS . . . Hammer, Press, Upset

MACHINING . . . Broaching, Milling, Turning, Drilling, Grinding

FINISHING . . . Heat Treating, Assembling, Painting, Plating

PORTER *FORGE & FITTINGS DIVISION*
H.K.PORTER COMPANY, INC.

PORTER SERVES INDUSTRY with steel, rubber and friction products, asbestos textiles, high voltage electrical equipment, electrical wire and cable, wiring systems, motors, fans, blowers, specialty alloys, paints, refractories, tools, forgings and pipe fittings, roll formings and stampings, wire rope and strand.

LIST NO. 232 ON INFO-COUPON PAGE 190

Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . .

ALLOYS
AZ10
AZ31
AZ51
AZ61
AZ81
ZK60
ZK30
M-1
ZK-20
Anodes

RODS ¼" dia. to 6½" dia.
BARS, STRIPS .022" min. to 7⅝" max
SOLID SHAPES .022" min. to 6½" circle
TUBING ¼" O.D. to 8" O.D.
HOLLOW SHAPES ½" to 6½" circle
PLATE & SHEET .092" to 3" thick

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.
82 Moultrie Street, Brooklyn 22, N.Y.
Factories: Brooklyn, N.Y. • Warsaw, Ind.
Los Angeles Warehouse: 6601 Telegraph Rd.

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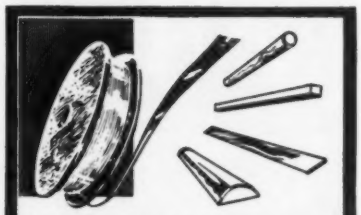

ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LFA LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

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MEET ALL TYPE FURNACE FIXTURE NEEDS . . . ECONOMICALLY.
PUSHER
SALT
PIT
BELL
No matter what type of heat treating furnace you have . . . complex or simple . . . a Wiretex-made fixture will handle it easier, better and at less cost.
Fixtures • Retorts • Baskets
Pots • Trays • Boxes • Grids
Screens • Muffles • Etc.
Any form, size, weight, strength, mesh, alloy or quantity.
Cost Conscious? Call Wiretex. Ask for Catalog M7
Specialists in Processing Carriers Since 1932.
Wiretex mfg. co., 5 Mason Street, Bridgeport 5, Conn.

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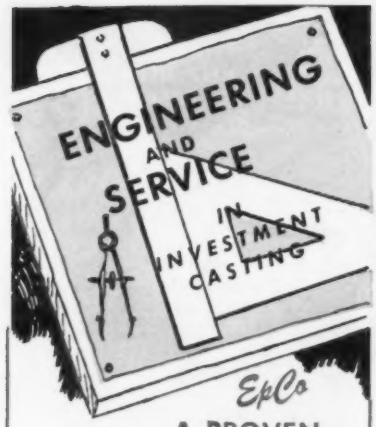
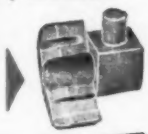


EpCo

A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.



ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

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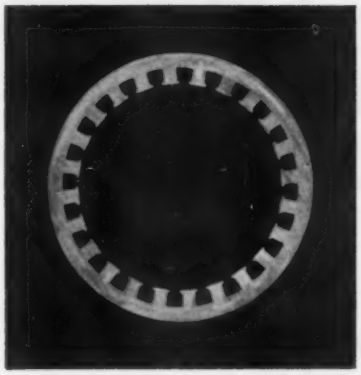

This die was ready for the customer 18 days after it was ordered

We can save you weeks when you need a new extrusion.

The die for the part shown above was producing vital parts for a leading industrial and appliance manufacturer 18 days after we received the order. It saved this customer time. It saved this customer money over machining such a part.

We have complete and modern facilities for fabricating and anodizing. We are a skilled producer of precision aluminum mouldings.

Chances are we can help you, too. Why not write us today.

Aluminum Extruders • Anodizers • Artrim Mouldings

SUPERIOR INDUSTRIES INC.

3786 Oakwood Ave., Youngstown, Ohio

LIST NO. 250 ON INFO-COUPON PAGE 190

DOW

BATCH FURNACES

CONTROLLED ATMOSPHERE EQUIPMENT FOR EVERY APPLICATION

STANDARD HEARTH SIZES

20" Wide—30" Long

24" Wide—36" Long

30" Wide—48" Long

LIST NO. 230 ON INFO-COUPON PAGE 190

IDENTIFY PARTS FOR HEAT TREATING!

Markal

PAINTSTIK MARKERS "M" and "M-10"

Mark any parts while cold, identify them after heat treating regardless of temperatures and oil or water quenchings. Use "M" up to 1600° F., "M-10" up to 2400° F.

WRITE ON LETTERHEAD FOR complete Paintstik information.

MARKAL COMPANY
3118 West Carroll Ave. Chicago 12, Ill.

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STOP CARBURIZING, DECARBURIZING, SCALING DURING HEAT TREATMENT!

Markal

"C-R" COATINGS

MARKAL "C-R" COATINGS will protect a wide range of metals at temperatures up to 2100° F. against carburizing, corrosion, scaling and the like. Coatings are easily applied, easily removed after treating.

WRITE ON LETTERHEAD FOR complete Coating information.

MARKAL COMPANY 3118 West Carroll Avenue • Chicago 12, Illinois

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All The Best

HEAT RESISTING ALLOYS

Ready When You Need Them

Please Send for Stock List and Literature

ROLLED ALLOYS, INC.

Heat and Corrosion Resistant Alloy Specialists

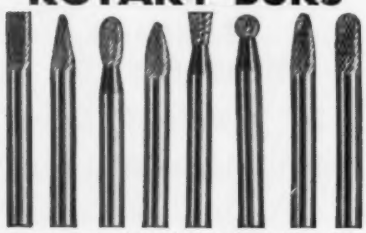
5309 Concord Avenue • Detroit 11, Michigan
Phone WAlnut 1-4462

330 William Street • South River, New Jersey
Phone CLifford 4-4616

LIST NO. 234 ON INFO-COUPON PAGE 190

MARTINDALE

ROTARY BURS



Solve toughest metal-cutting jobs. Martindale Carbide Rotary Burs and Files cut the toughest metals and abrasive materials. Precision ground from solid carbide, in wide selection of shapes and sizes 3/32 to 1 in. diameter. Available in identical shapes, sizes in high-speed steel.

Send for NEW CATALOG including hundreds of cost-saving items for maintenance, safety, production.

MARTINDALE ELECTRIC CO.

1372 Hird Avenue Cleveland 7, Ohio

LIST NO. 216 ON INFO-COUPON PAGE 190

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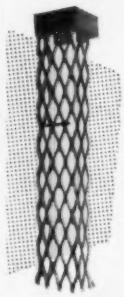
there's a

Glo-QUARTZ* **IMMERSION HEATER**

for

Your Every Heating Requirement



- **INSTANT HEATING**
- **SHOCK-PROOF**
- **AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE**

Available from your Electroplating Distributor

WRITE FOR BULLETIN ▶

Glo-QUARTZ*

ELECTRIC HEATER CO., INC., Willoughby, Ohio

*Reg. U.S. Pat. Off. Phone: Willoughby 2-5521

LIST NO. 145 ON INFO-COUPON PAGE 190

● It's cold inside Universal Cabinet's Model GT-23. Separating this frigid atmosphere from the warm temperatures outside is a fog-free glass . . . framed in anodized aluminum extrusions by G.E.I. The G.E.I. sections perfectly fit both the glass and the cabinet, slide freely and add beauty to the cabinet.

This is another example of a leading manufacturer solving his requirements for durability, beauty and economy with extrusions by G.E.I.

GENERAL EXTRUSIONS, INC.

4040 Lake Park Road • Youngstown, Ohio

Sales Offices at St. Louis, Pittsburgh, Chattanooga and Cleveland

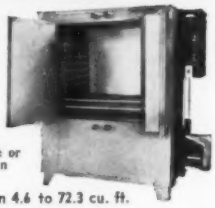
Consult your Classified Phone Book Under Aluminum Products

LIST NO. 141 ON INFO-COUPON PAGE 190

UNIFORM HEAT

throughout the work space

30 STANDARD CABINET MODELS



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FREE

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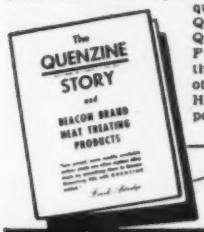

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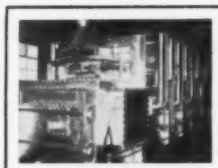

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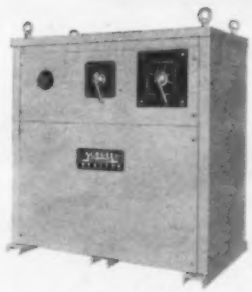
Saturable Reactors



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The control can be a small manually operated hand wheel that can be placed in any desired location, or it can be automatically controlled, regulated and varied by a thermostat or any other instrument or device.

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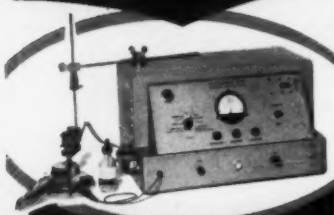

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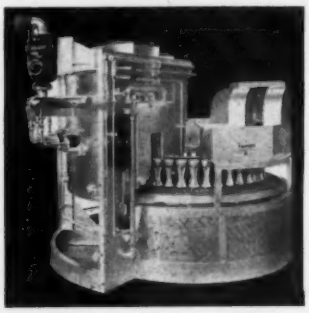

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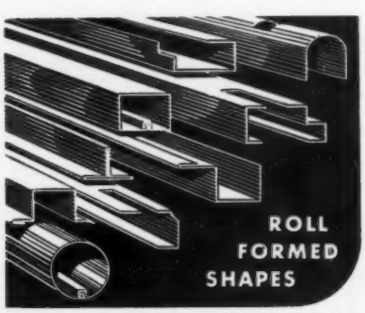

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More and more firms are relying on the high contrast and development latitude of Du Pont Type 510 Industrial X-ray Film to meet exacting standards of inspection—particularly where government specifications are involved.

Now Du Pont research has succeeded in combining this fine grain emulsion with the unique CRONAR* polyester film base. Result: CRONAR 510, an outstanding new industrial x-ray film that provides exceptional optical clarity and cleaner, more vivid images on the most rugged dimensionally stable base ever developed.

CRONAR 510 has been thoroughly evaluated in the field by companies engaged in research and development work on nuclear fuel plates. By virtually eliminating distortion, the built-in stability of CRONAR is of prime importance in enabling them to meet consistently rigid requirements of quality and reliability.

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BETTER THINGS FOR BETTER LIVING ... *THROUGH CHEMISTRY*

Shot-Peening . . .

ing, surface rolling, plating, and low-temperature baking. The 2.5% Ni steel was also subjected to axial loading tests, in the electropolished and the plated conditions only. This made it possible to isolate the effects of compressive stresses from those of cold work, both of which are associated with shot-peening and surface rolling.

The rotating-bending tests will be considered first. With conventional chromium plating to a thickness of 0.006 in., fatigue limits were lowered 40 to 50% below the par values for the steels established on the basis of the electropolished bars. However, fatigue limits went up with increasing intensity of shot-peening prior to plating, the par values being either closely approached or slightly exceeded when the peening intensity on an Almen test strip was 0.015 A 2. Residual stress measurements on such a test strip showed that this intensity corresponded to a compressive stress of about 100,000 psi. at a depth of 0.002 in. below the surface. Rolling the surface with a rounded and hardened steel disk (1 in. diameter) before plating caused the fatigue limit to rise with increasing rolling load, but the highest value attained was still about 10% below the par value.

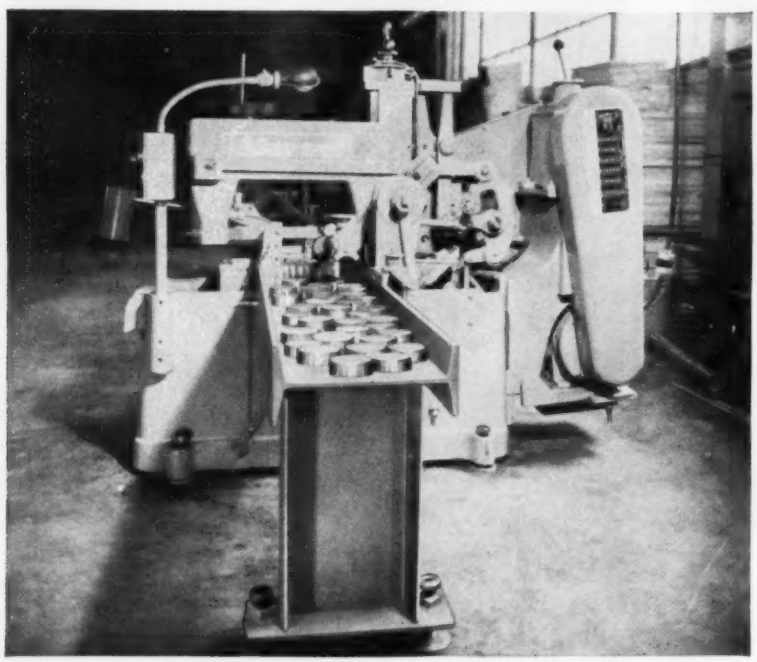
When *unpeened* chromium-plated bars were ground properly, the fatigue limit was slightly higher than for similar bars that had not been ground, in agreement with the results obtained previously by others on lower-strength steels. This improvement is tentatively ascribed to the smoother finish produced by grinding*. The fatigue limit for the *peened* and plated bars was practically unaffected by grinding, whether this was done before plating, after plating, or both before and after. Here, the peened steel was ground to a depth of only 0.0015 in., enough to eliminate completely the surface irregularities caused by peening, but not enough to remove a significant portion of the compressively stressed and cold worked layer. The fatigue limit did drop a little when the peened surface was ground to a depth of 0.004 in.

Low-temperature baking at 375 to 390° F. did not affect the fatigue limit of *peened* and plated specimens, whether or not they had been ground either before or after plating. This is in contrast to the deleterious effect of similar baking on the fatigue limit of *unpeened* and plated steels. The explanation offered for these effects is that the low-temperature bake sets up tensile stresses in the chromium plate which either result in immediate cracking of the deposit or in delayed cracking during the fatigue test. Such cracks propagate readily into the unpeened steel, but not into the compressively stressed and cold worked surface of the peened steel. The compressive stresses in the steel were not measurably affected by the low-temperature bake.

Axial fatigue tests, performed on unpeened specimens which were in the electropolished or plated conditions, showed that the application of a compressive mean stress raised the fatigue limit as expected, while a tensile mean stress lowered it, the percentage reduction being appreciably greater for the plated than for the unplated material.

This work indicates that shot-peening is an effective way of preventing the marked reduction in the

*An alternative explanation offered by the reviewer is that the chromium surface was cold worked and compressively stressed by grinding. This strengthened it, as has been found to happen with hardened steel.



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PRODUCTION? Constant at 20 pieces per hour floor to floor

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BLADE COST? Just 1½¢ per cut. Only twenty-three MARVEL blades were needed to make the 4600 cuts, and not a single blade failure due to blade breakage. MARVEL High-Speed-Edge Blades are unbreakable.

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MMT-PE

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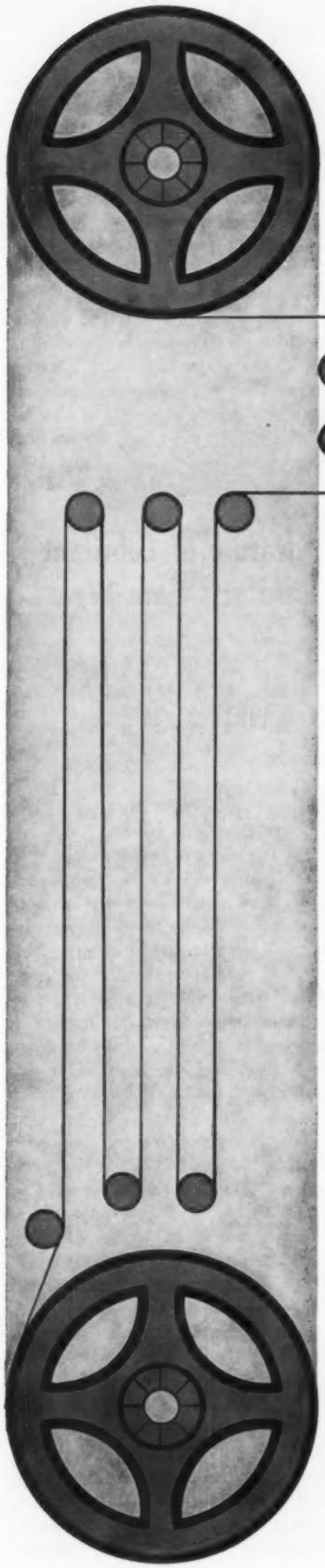
MARVEL Metal Cutting SAWS

Circle 1385 on Page 48-A



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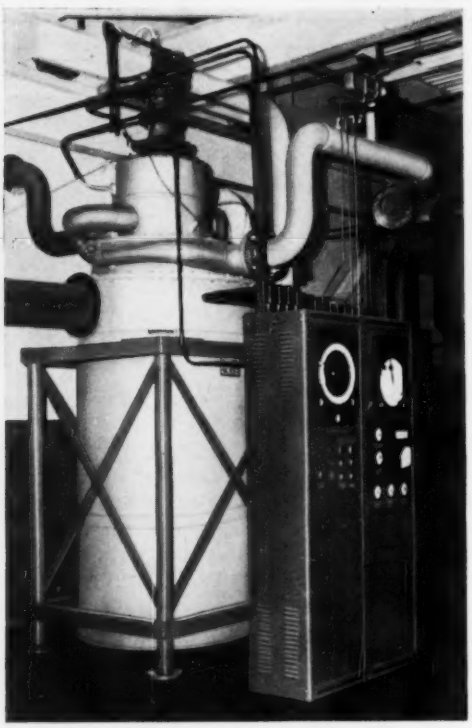

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Bulletin #112 describes direct fired air heaters and Bulletin #113 covers the indirect fired heaters.

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Circle 1386 on Page 48-A

Shot-Peening . . .

fatigue properties of high-strength steels which otherwise occurs when they are chromium plated. Also, the beneficial effect of peening is not affected by the low-temperature bake necessary to eliminate hydrogen embrittlement nor by the grinding needed to provide a smooth finish. If the chromium deposit is thin, the peened steel can be ground smooth prior to plating, but if the deposit is thick, it is more economical to grind the chromium itself. It was found that surface rolling prior to plating overcame most, but not all, of the reduction in the fatigue limit caused by plating.

L. P. TARASOV

Nature of Lubricant Affects Gear Wear

Digest of "Measurement of Gear Wear by Activating Particles in the Lubricant", by Harvey D. Briggs and John F. Coultry. Paper presented at the Nuclear Engineering & Science Conference, Cleveland, April 1959.

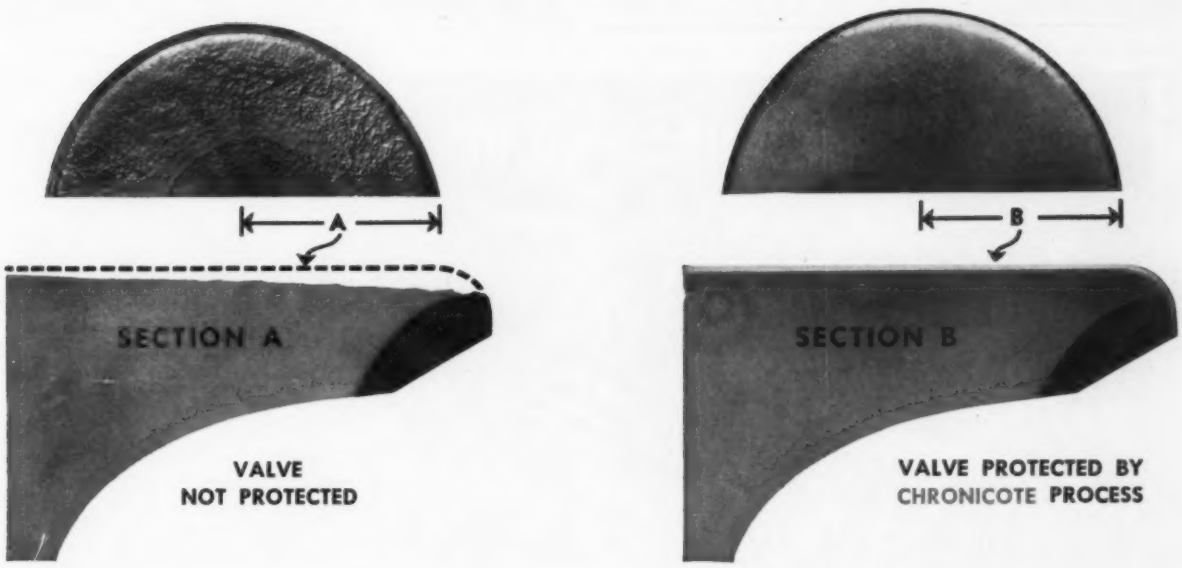
MANY WEAR TESTS have been made on gear sets, bearings and cylinder lines by irradiating one or both of the units which rub against each other and determining the amount and nature of the worn-off particles carried away on the lubricant. This method is unacceptable if the parts under study are too large to be irradiated in any available facility, if it is undesirable to hold the lubricant in a tightly closed loop, or if *any* radiation hazard must be avoided in the plant.

An alternative method has been used in the general engineering laboratory of General Electric Co., wherein identical gear sets were operated for 25 hr. under standardized conditions except for lubricant, 10 cc. of oil being removed at stated times, the oil with entrained particles then irradiated to activate certain metallic elements, and the radiation so induced measured with a gamma-ray spectrometer.

First, the piping and pumps in the circulating system must be free of traces of the elements manganese and aluminum suitable for such testing and contained in the gears. Aluminum was the larger compon-

CHRŌNICŌTE

A New Low-Cost Corrosion-Resistant Valve Head Coating that Eliminates Deposit-induced Preignition



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We will be glad to furnish your engineers with technical reports covering life comparisons between CHRONICOTE and unprotected valves. We believe you will agree that Eaton CHRONICOTE Valves provide the long-sought solution to the problems of rapid corrosion and deposit-induced preignition. Write, wire or phone.

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Circle 1387 on Page 48-A

Gear Wear . . .

ent, 1.20% in the gears, and it could be irradiated in a linear accelerator in the G.E. laboratory – a fortunate circumstance since Al^{28} has a half-life of only 2.3 min. so the spectrographic analysis had to be made very promptly. However, aluminum could not be used as a target if there were any contamination from silicon, for similar irradiation of Si^{28} also produces Al^{28}.

When manganese was used as the trace element, difficulties arose because of its low content in the gear alloy (0.55%), and its activation required much higher neutron flux than given by the available linear accelerator. Such samples were sent to Brookhaven National Laboratory and irradiated 5 hr. in the atomic reactor at a neutron flux of about 10^{12} nv. This produced a number of activities; the interesting one (from manganese) was measured by comparing the spectrograph of an oil sample containing a known amount of $MnCl_2$. The half-life of Mn^{56} is 2.6 hr. so a reasonable delay was permissible for transporting the samples from the reactor to the spectrograph.

Results for three varieties of lubricants show that wear is quite rapid for about 4 hr. (the "breaking-in period"). At that time wear amounted to 45, 90 and 200 arbitrary units for Oils No. 3, 2 and 1, respectively. From then on, up to 25 hr., the limit of the test, wear was at a fairly steady rate, being 0.25, 1.25 and 5.0 units per hr. for Oils No. 3, 2 and 1. E.E.T.

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COLD mark anything down to —50° F.

HOT white hot heat as high as 2400° F.

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WRITE TODAY on company letterhead for catalog. Give details on marking problem for free sample.

Circle 1388 on Page 48-A

Silicon-Iron Orientations

Digest of "Preferred Orientation in Silicon-Iron", by P. N. Richards, *Journal*, Australian Institute of Metals, Vol. 4, No. 2, August 1959.

THIS PAPER reviewed the development of the {110} <001> "cube-on-edge" texture and of the {001} <100> cube texture in electrical steel containing 3% silicon, balance iron by weight. Several techniques were discussed for measuring textures: *(a)* torque magnetometer, *(b)* optical goniometer, and *(c)* core loss measurements.

Experiments were described on the growth of the {110} <001> texture. Silicon-iron strip was processed by a cold reduction, intermediate anneal, and further cold reduction to 0.013 in. in final thickness. Subsequently, the strip was decarburized by annealing in wet hydrogen. At this stage, primary recrystallization had occurred, and torque magnetometer measurements showed the presence of a weakly developed {110} <001>.

Sections of the decarburized strip were annealed isothermally for times varying from 1 to 160 min. at temperatures ranging from 1000 to 1180° C. (1830 to 2150° F.). An increase in annealing temperature was observed to have the following effects: *(a)* The time required for complete secondary recrystallization to near {110} <001> decreased, *(b)* the grain size after secondary recrystallization decreased, and *(c)* the perfection of the {110} <001> decreased as indicated by torque curves.

In practice, the best core losses

B&W Kaocrete-D, vibrated in place, provides high resistance to the atmospheres encountered in this coke oven door installation. Furthermore, the high erosion resistance and long service life without loss of strength of B&W Kaocrete-D add to its suitability in this application.

A typical monolithic curb wall construction in an annealing furnace using a carbon monoxide atmosphere. The greatly reduced number of joints in which sealing sand can penetrate prevents structural spalling of B&W Kaocrete-A upon heating and cooling. Being monolithic, gas leaks are practically eliminated.

A radiant tube annealing furnace with a base of Kaocrete-A, backed up with Kaolite-20, one of B&W's insulating refractory castables. This furnace operates at approximately 1700 F in a 65% CO atmosphere.

A stack annealing furnace with pedestals cast of B&W Kaocrete-A. The atmosphere is slightly above 8% CO. B&W Kaocrete-A offers strength, volume stability and resistance to carbon monoxide disintegration.

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B&W Bulletin R-35A gives additional information on versatile B&W refractory castables. Write for your copy of this bulletin to The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, N. Y.

R832

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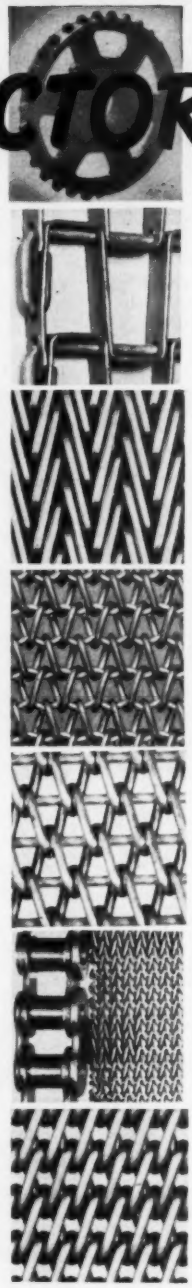

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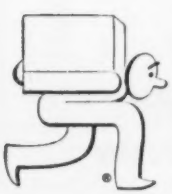

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Circle 1390 on Page 48-A

Si-Fe Orientations . . .

and perfection of texture were obtained by a two-stage final anneal involving an isothermal stage at 1000° C. (1830° F.) and one at 1180° C. (2150° F). The development of the {110} <001> by secondary recrystallization was considered to result from impurity inhibition of growth. That is, second-phase impurities were considered to inhibit normal grain growth. At a temperature near 1000° C. (1830° F.), slow dissolution of these impurities was considered to allow certain favored grains to break through the growth-restraining barrier and grow at the expense of the matrix. Impurities were second-phase inclusions such as carbides, sulphides, nitrides, and possibly oxides. The role of nitrides was discussed in detail.

ROBERT ASPDEN

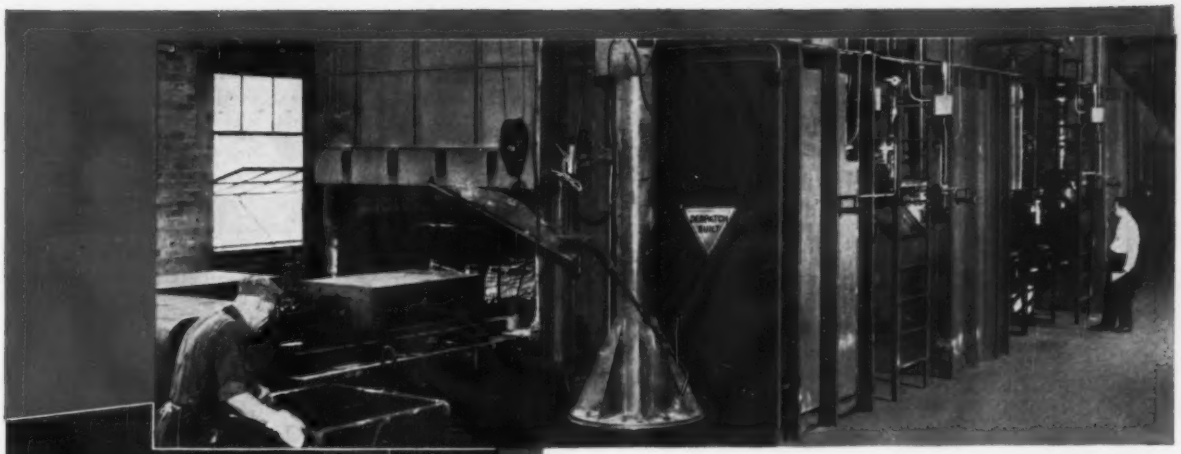
Tungsten at High Temperatures

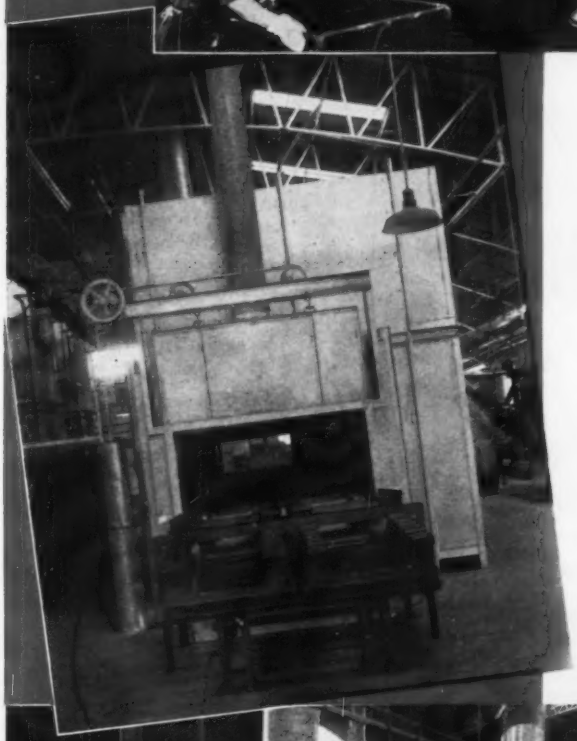
Digest of "High-Temperature Tensile Properties of Wrought Sintered Tungsten", by Paul F. Sikora and Robert W. Hall, Technical Note D-79, September 1959, National Aeronautics and Space Administration, Washington, D. C.

REFRACTORY METALS are becoming increasingly important as potential structural materials in high-speed aircraft, missiles, and space vehicles. Tungsten, in particular, is being considered because of its high melting point (6170° F.) and relatively high strength above 3000° F. However, information on the mechanical properties of tungsten above 2500° F. is limited.

In a previous study, it was observed that tungsten exhibited a decrease in ductility above about 3100° F. A prime purpose of this investigation was to determine whether this is generally characteristic of commercially pure tungsten or of only the one lot of material previously evaluated.

Specimens from ½-in. diameter, commercially pure, sintered and swaged bars supplied by five producers were evaluated in short-time tensile tests at 2500 to 4400° F. Results showed that the decrease in ductility of tungsten at high tem-





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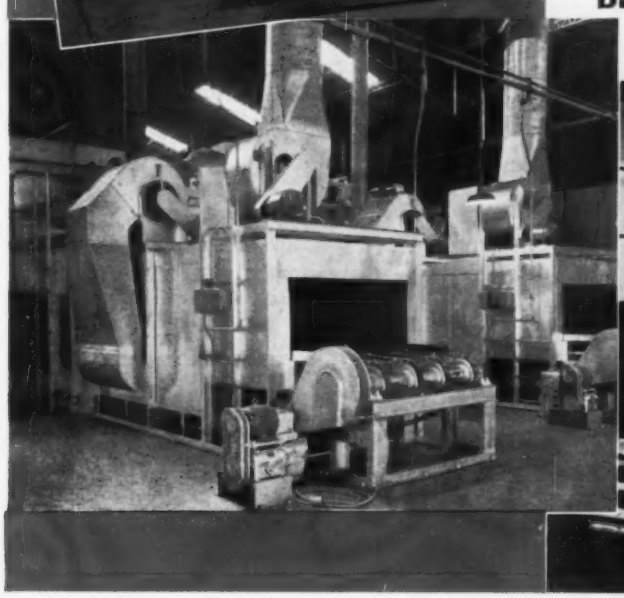

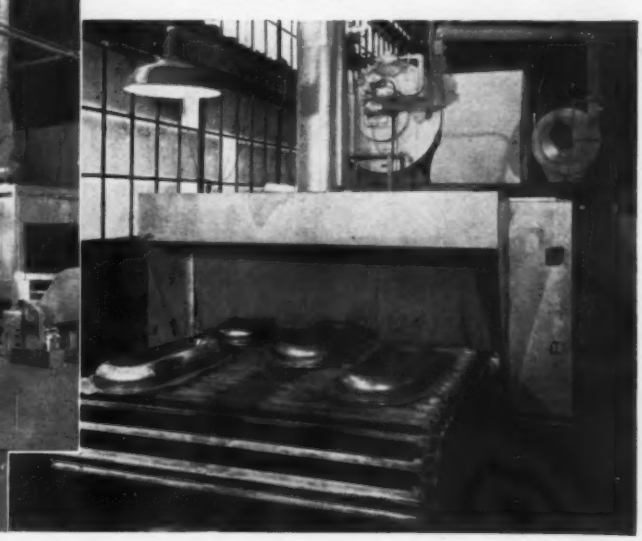

Circle 1391 on Page 48-A

Tungsten . . .

peratures is characteristic of commercially pure sintered tungsten. However, an appreciable amount of ductility is still retained up to 4400° F.

The tensile strength of tungsten decreases relatively slowly in the 3500 to 4400° F. range. Average values of tensile strength for the specimens evaluated were 10,600 at 3500° F., 6500 at 4075° F., and 4400 psi. at 4400° F. The decrease in ductility of tungsten with increasing temperature above 2500° F., as measured by reduction in area at fracture in tensile tests, appears to be characteristic of commercially pure sintered tungsten. Material from five different producers behaved similarly in this respect.

There were, however, some differences which may be significant. For example, materials from different sources exhibited widely differing amounts of porosity in the fracture region after tests at 2500° F. This porosity in the fracture zone apparently does not seriously affect the tensile strength of tungsten.

Metallographic examination also revealed that there were significant differences in grain size of the materials at temperatures above 3500° F. There did not, however, appear to be any correlation between grain size and high-temperature strength or ductility. A.G.G.

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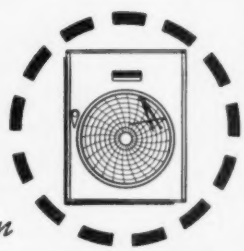

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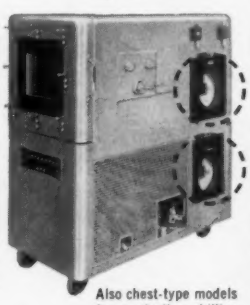

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Circle 1392 on Page 48-A

Explosive Forming Studies

Digest of "Studies of Metals at Ballistic Rates of Loading", by J. O'Brien and R. S. Davis. Paper presented at a Symposium on High Speed Testing sponsored by Plas-Tech Corp. All papers presented will be published by Interscience Publishers, Inc.

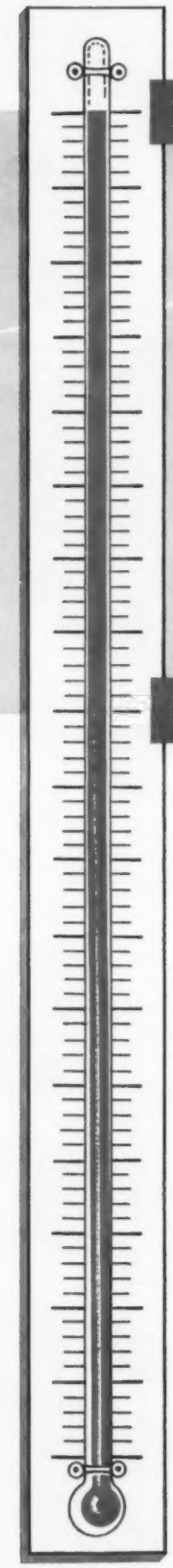
A COMPRESSION PULSE may be induced in a solid material by the application of a very high pressure to one surface, if the pressure is maintained momentarily and suddenly withdrawn. If this compression pulse encounters a free surface parallel to its wave front, it will be reflected as a tension pulse, and will fracture the specimen when the magnitude of the tensile stress exceeds the strength of the material.

The detonation of a high explosive in contact with the surface of a specimen will produce a compression pulse in the shape of a right triangle with the altitude being the wave front. For a steep fronted pulse of this type, the maximum tensile stress is obtained when the pulse is reflected from the free surface for a distance equal to one half its length. However, fracture will occur at that point where the tensile stress equals the fracture stress. Therefore, if the stress distribution in the pulse is known, the fracture stress of the material under these loading conditions may be obtained by increasing the distance of the fracture surface from the free surface.

Fracture stress was determined for a number of aluminum alloy specimens ranging from 99.993% Al to 95% Al, 5% copper (2024-T 4 alloy). This stress was found to be 240,000 psi. ±20,000 psi. The fracture stress was found to be independent of the composition (over the range studied)

(Continued on page 204)

Metallurgical Memo from General Electric



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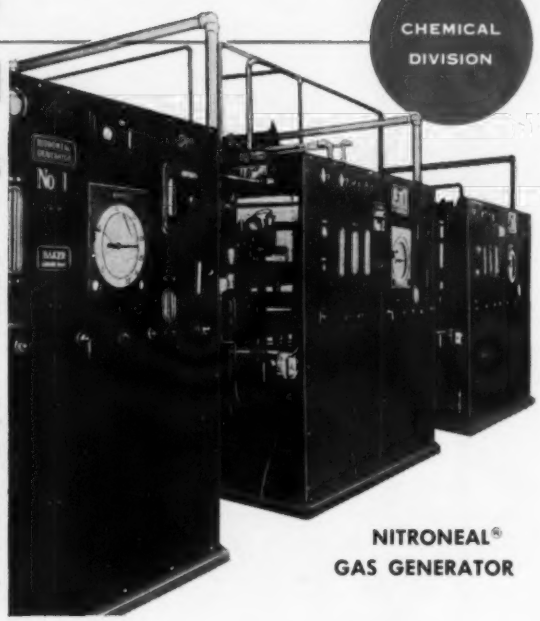

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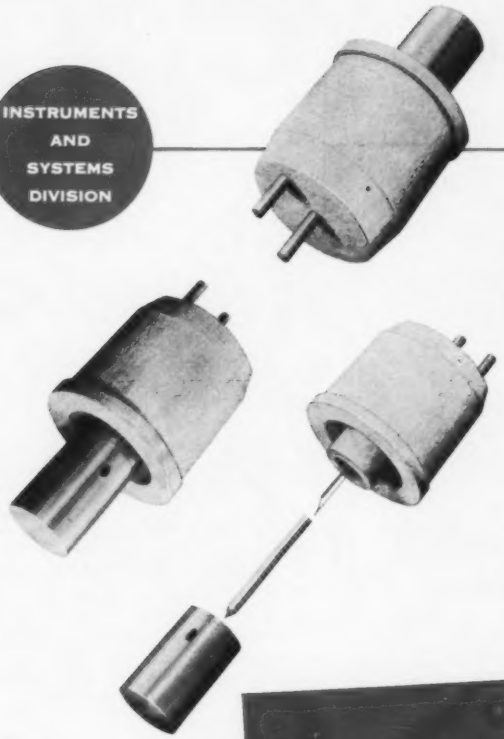

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Circle 1394 on Page 48-A

Explosive Forming . . .

and also independent of structure over a range of structure whose limits were a single crystal and 2024 alloy in the T-4 condition.

BERNARD TROCK

Bright Chromizing

Digest of "New Thermo-Chemical Techniques, Part I — Bright Annealing", by P. Galmiche, *Metal Finishing Journal*, March 1959, p. 113-116.

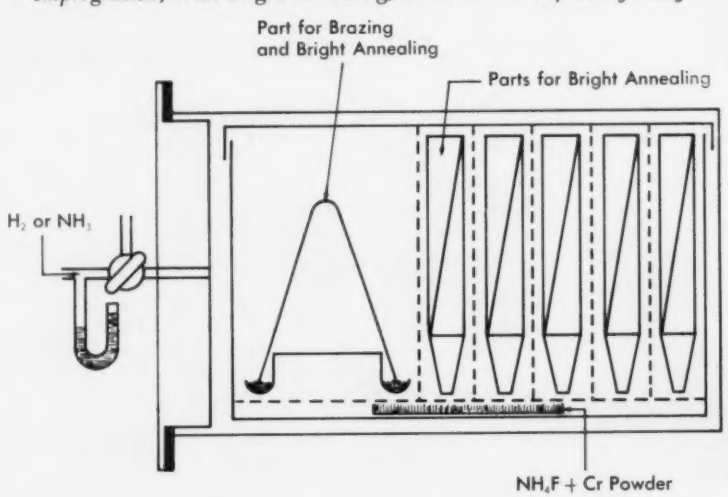
THE "ONERA" PROCESS of bright chromizing diffuses chromium into the surface of the pieces being treated, and imparts to them a bright chromium surface. This process has resulted in the development of new thermochemical techniques for bright annealing of steel and refractory metal alloys, and for the brazing of assemblies containing one or more elements made of a chromium alloy. These other techniques can be carried out in the same equipment used for the basic process. The following is a brief description of the annealing process.

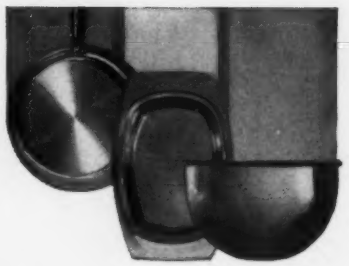
Items to be annealed are placed inside a nearly airtight box which contains powdered or granulated ammonium fluoride with chromium or ferrochromium. The ammonium fluoride may be in contact with the workpiece, but the chromium (or ferrochromium) may not. The boxes are placed in a furnace with a neutral or reducing atmosphere of ammonia or hydrogen at normal or reduced pressure, and heated (see Fig. 1). Upon heating, the ammonium fluoride reacts with the chromium, and is dissociated. This reaction results in the formation of a low volatile reserve of chromium fluoride plus a mixture of hydrogen, nitrogen, and hydrofluoric acid gas. These gases drive the air out of the treatment boxes, and form a very thin skin of low volatile fluorides on the surfaces of the workpieces.

At a high temperature (about 1850° F.), the protective fluoride skin is reduced together with a part of the reserve chromium fluoride until equilibrium is attained for that temperature. The reserve chromium fluoride keeps the halogen reducing atmosphere content.

Workpieces made of iron, nickel, or cobalt alloys containing a relatively high percentage of chromium can be annealed in this atmosphere without any chemical disturbance of the surface areas. After cooling, they can be removed with a very bright surface provided the temperature has been high enough. Temperatures below 800 to 900° C. (1470 to 1650° F.) may result in discolored surfaces due to the presence of unreduced fluorides. If the treated workpieces are made of alloys containing volatile stable fluorides such as silicon and titanium, these elements are partially eliminated just below the surface. If carburized workpieces are treated, there may be a slight decarburiza-

Fig. 1 — Installation Used for Bright Annealing and Brazing or for Impregnation, With Bright Annealing, or Steels and Refractory Alloys





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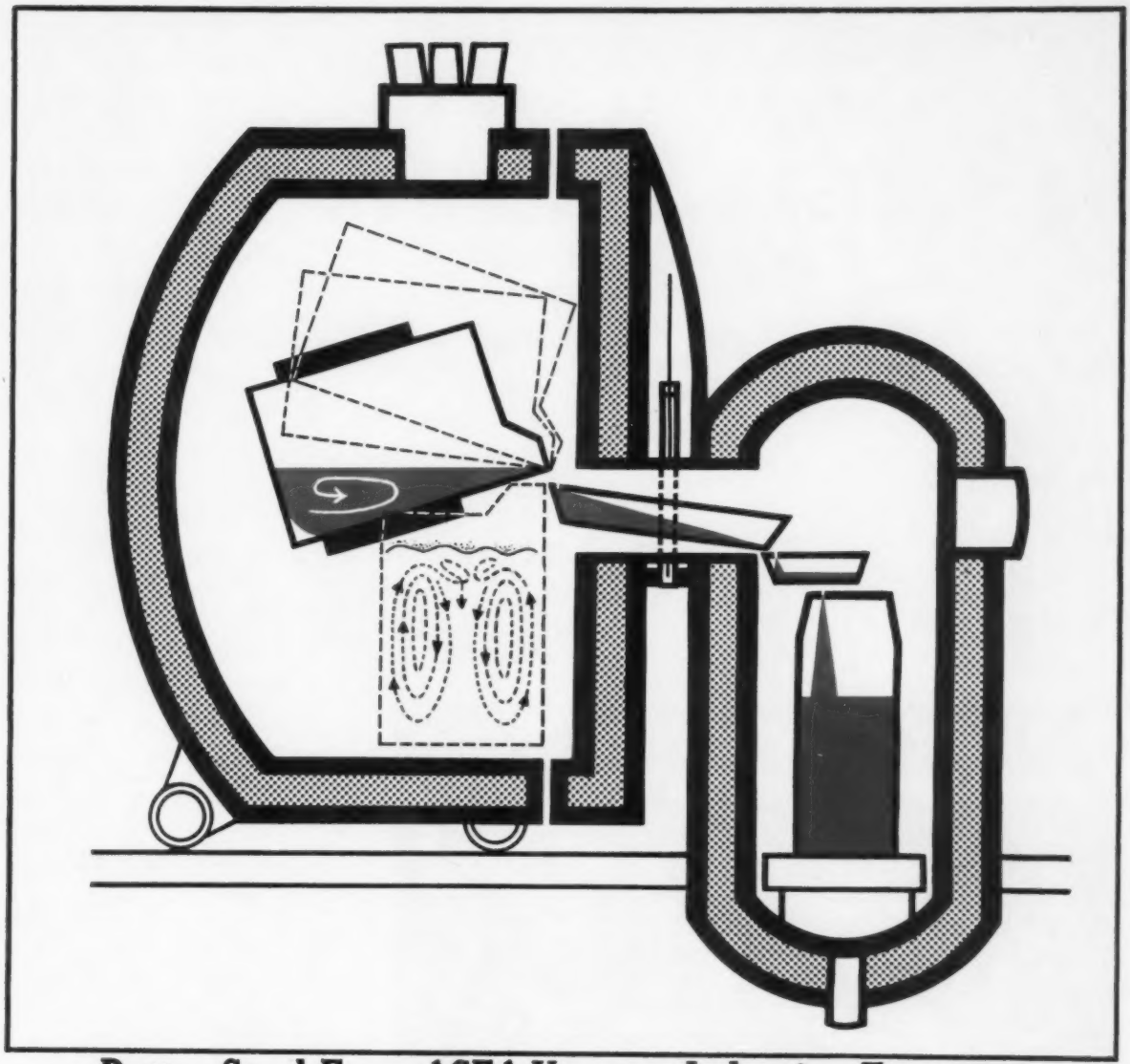

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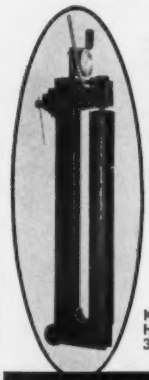

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Circle 1398 on Page 48-A

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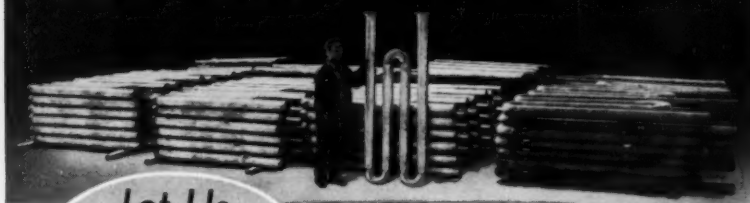

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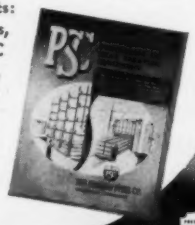

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THE PRESSED STEEL CO. · Wilkes-Barre, Pa.

Circle 1399 on Page 48-A

Bright Chromizing

tion of the surface zone. Furthermore, if oxidized items are treated, there will be a quantitative deoxidation of the surface with the metallic oxides being either transformed into fluorides and eliminated (such as silicon and titanium) or reduced (such as chromium, iron, nickel, and others). Most of the material used in this process is recoverable and can be used over and over again. However, it is necessary to add a small amount of acid or ammonium fluoride after each operation.

The brazing process can be integrated into the annealing process. The assemblies obtained in this manner are of exceptional quality and leave a bright finish. Furthermore, since the surfaces of the pieces being brazed are deoxidized before the brazing material melts, no fluxes are needed. Refractory metals and alloys such as tungsten and molybdenum can be very satisfactorily brazed in this manner by using chromium alloys with melting points ranging from 1150 to 1375° C. (2100 to 2500° F.) as brazing materials.

B. Trock

Carbide Hardness

Digest of "A Cooperative Study of the Hardness Testing of Cemented Carbides", by B. M. Caugherty, H. T. Oatman and O. W. Reen, A.S.T.M. Preprint No. 79. Paper presented at the 62nd Annual Meeting of A.S.T.M., June 1959.

Serious discrepancies in test data of cemented tungsten carbide exist between producers and customers and between the producers themselves. This has led to efforts to standardize testing procedures. The first phase of a test program developed by the technical committee of the Cemented Carbide Producers Association was a cooperative study by 14 companies. This was centered on the Rockwell hardness test using a Brale diamond indenter under a 60-kg. load with hardness indicated by the Rockwell A scale.

Evaluation of the testing procedures followed by the member companies of the association revealed wide variations in such testing conditions as sample preparation, anvil size, calibration methods, and oper-

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Circle 1400 on Page 48-A

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Carbide Hardness . . .

ator techniques. Most of these variables can, at best, be described only qualitatively.

Two round robin tests were conducted. The first used one set of six blocks with hardness levels ranging from Rockwell A-84.5 to 93.0. All testing of these blocks was conducted under prescribed conditions in which each machine was calibrated by the same calibrating blocks. Each machine was thus calibrated to the same hardness level, and variations in results were due to other factors. The second test used a set of four blocks with hardness levels ranging from Rockwell A-86.5 to 92.0. Each machine was calibrated by the calibrating blocks of the individual companies. This test determined variations in hardness between companies when the usual testing procedures were followed.

Statistical analysis of the results indicates that the expected range of variation between any two companies is 0.4 to 0.6 points on the Rockwell A scale when common calibrating blocks are used. The expected range of variation is 0.8 to 1.5 hardness points when each company uses its own calibrating blocks. In both instances, the lower range value applies to the hardest test block and the higher range value applies to the least hard block.

Variations in the test results come from three sources: (*a*) Precision of the testing equipment and technique of the operator, (*b*) real differences in block hardness from point to point and over the area of the sample, and (*c*) calibration. In practice, the first two effects can not be separated and the combination can be considered as "precision of measurement". The methods of standards used for calibration may introduce a real bias for any particular test specimen, or the calibration may not be sufficiently precise.

The test program is continuing with an investigation of the metallurgical variables of test blocks of cemented carbides in the hope of providing suitable standard test blocks.

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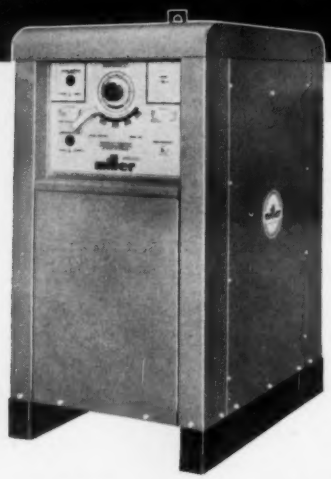

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Circle 1401 on Page 48-A

Joining Dissimilar Steels

Digest of "Ferritic-Austenitic Weld Joints in Thermal Power Stations", by F. Zimmer, *Revue de Metallurgia*, Vol. 3, October 1957, p. 162-174; translated and digested in *Engineers' Digest*, Vol. 19, March 1958, p. 99-102.

THE USE of ferritic steels for high-pressure power plant piping becomes impractical above 1050° F. because of the decreasing mechanical strength and oxidation resistance of these steels. On the other hand, the complete use of austenitic steels in these stations becomes uneconomical and, therefore, the best and most economical design frequently rests upon the use of both types of steel connected at some point by a ferritic-austenitic transition joint. A common ferritic steel used in these applications is 2.25 Cr, 1.0 Mo, while the austenitic is usually a stabilized 18-8 grade. The joints may be formed by welding with some high-alloy austenitic weld electrode, by butt welding, forge welding, mechanical means or combinations of several of these methods. *(Continued on page 212)*

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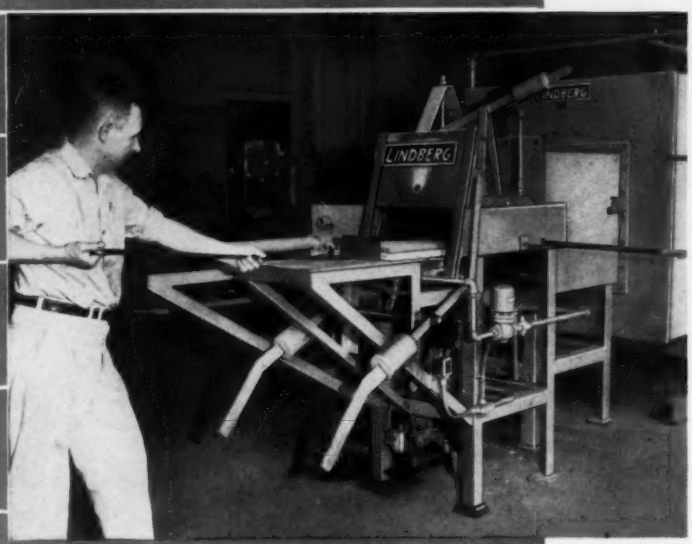
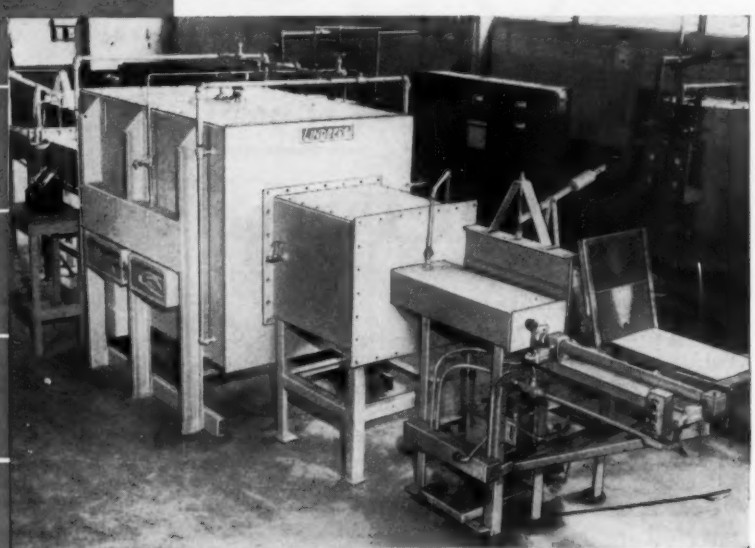
Circle 1402 on Page 48-A

NEW LINDBERG FURNACE PROVIDES IMPROVED EFFICIENCY FOR STAINLESS STEEL SINTERING

This Molybdenum Element Atmosphere Pusher Type Furnace embodies high temperature refractories suitable for low dew point without muffle



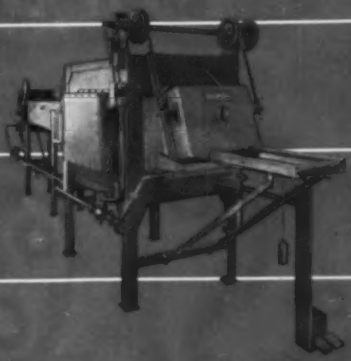
This new furnace provides an improved method for sintering stainless steel compacts in hydrogen or dissociated ammonia. A development of Lindberg's engineering staff, you can depend on the most efficient, economical and trouble-free service from it. Furnace provides side loading and discharge parts with purging chambers. Work trays, ceramic slabs or molybdenum boats, move through the furnace by hydraulic pusher. In the installation illustrated below ammonia dissociator and control panels are shown at the right. Hydrogen supply cylinders are located outside the building. For full information on this and Lindberg's complete line of sintering and brazing furnaces just get in touch with your local Lindberg Field Representative (see classified phone book) or write us direct. Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.



Type MOP-1236T-A88C Molybdenum Element Atmosphere Pusher Furnace. Maximum Temperature 3000° F. 60 KW input. 12" wide, 30" long, 7" high. 60" cooling chamber, 36" long preheat chamber.

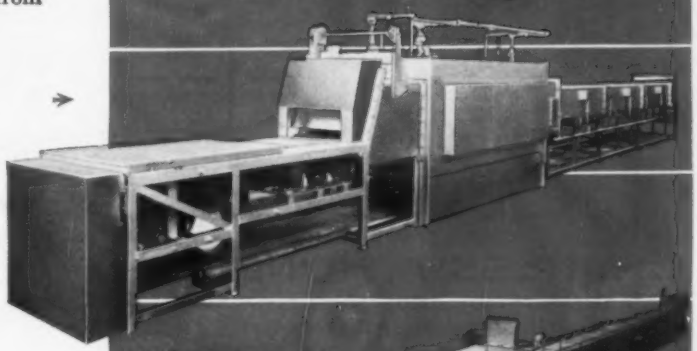
LINDBERG heat for industry

As it does in all types of industrial heating equipment, Lindberg provides a complete line of sintering and brazing furnaces. For example:



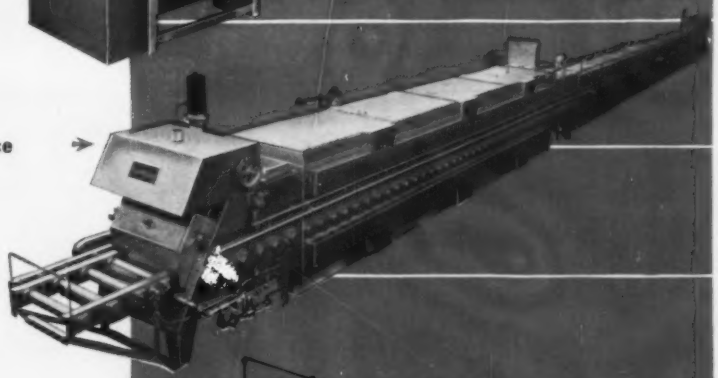
This Hand Pusher Batch Type Furnace →

is used for small production lots and experimental sintering. It is an all-purpose unit for operation from 1300°F to 2500°F. Made in various sizes for sintering from 25 to 300 pounds per hour.



This Mesh Belt Continuous Type Furnace →

is a popular sintering furnace for small light parts in copper, bronze, brass or steel with a temperature range from 1300°F. to 2100°F. It can be used for low temperature silver brazing, bright annealing, as well as sintering of powder metals. Production ranges up to 500 pounds per hour.



This Roller Hearth Continuous Type Furnace →

is especially designed to handle heavier loads up to 2200 pounds per hour. It has an effective temperature range from 1300°F. to 2100°F. It can be used for bright annealing, low temperature silver brazing as well as sintering of powder metals.

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To obtain the best work from any sintering furnaces, the proper atmosphere is required. The atmosphere generators described here provide the proper atmospheres recommended for use with Lindberg Sintering Furnaces.

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2. The HYEN Generator produces a neutral atmosphere composed of approximately 21% carbon monoxide—40% hydrogen—39% nitrogen and 1% methane.

3. The HYAM Generator produces atmosphere composed of approximately 75% hydrogen and 25% nitrogen.

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Circle 1403 on Page 48-A

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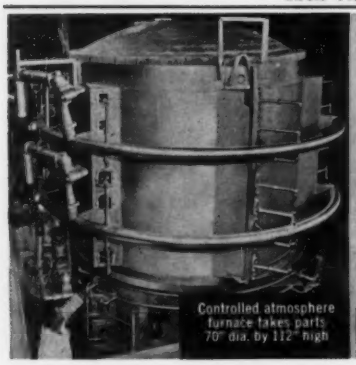
Circle 1404 on Page 48-A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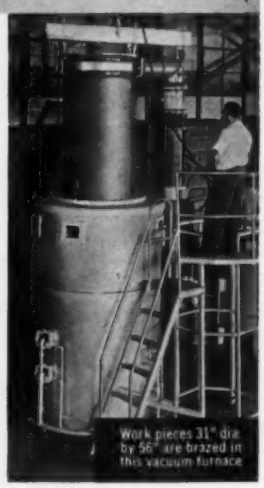
Work pieces 31" dia. by 56" are brazed in this vacuum furnace

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Wall Colmonoy furnace plants are maintained in Michigan, Pennsylvania, Ohio, and California

Circle 1405 on Page 48-A

Joining . . .

This paper reviews the design and practices used in Europe and in this country to fill these needs for transition joints. The principal technical difficulties which must be solved in this application are:

1. The severe thermal stresses set up as a result of the different thermal expansion characteristics in the two base metals.
2. Occurrence of grain growth and embrittlement in the ferritic material next to the weld as a result of carbon migration to the austenitic component.
3. Susceptibility to stress corrosion in the decarburization zone of the ferritic steel.

Some sixteen different designs are reviewed and these serve to illustrate ways in which the problems may be answered.

To minimize the thermal stresses, several means have been followed. Auxiliary, thermostatically controlled, electrical heaters are frequently mounted on some joints to prevent this section of the piping system from becoming too cold during shutdown periods and this, thereby, eliminates or greatly minimizes the thermal stress problem. A purely metallurgical approach has also been taken whereby a transition piece of piping is used which has a coefficient of thermal expansion that is midway between those of the ferritic (14×10^{-6} per ° C.) and austenitic steels (18×10^{-6} per ° C.). Other designs use a progressive series of different high-alloy welding electrodes in which the expansion coefficients are varied by changing the nickel content.

The problem of carbon migration also has several solutions. Stabilizing the ferritic base metal or a ferritic facing bead of weld metal has been widely used. Another approach is to make a mechanical joint in which the mating surfaces are plated with a thin layer of nickel to suppress carbon diffusion. These mechanical joints may or may not be subsequently forge welded or seal welded.

The problem of stress corrosion cracking has been combated by special alloy protective overlays, which are deposited over the interface between the ferritic base metal and the main austenitic weld deposit.

In summary, this review describes

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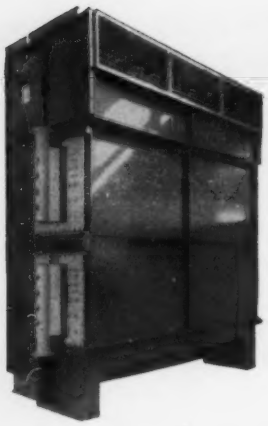

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Circle 1406 on Page 48-A

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Circle 1407 on Page 48-A

Joining . . .

a number of practical, successful methods of joining large sections of widely dissimilar steels; the techniques used may have useful application in other similar problems.

D. G. EBELING

Electric Steel Production

Digest of "Tonnage Production of Electric Steel in the United States", by F. B. O'Mara, Paper presented at IV International Congress on Electro-Heat, Stresa, Italy, May 1959.

THIS CLEAR, WELL-WRITTEN paper highlights the development in the extra large electric arc melting furnace in the United States since 1957. Since 1946, the annual electric furnace capacity in the United States has increased from 5,500,290 tons to 13,495,130 tons by 1959. These furnaces all have shells 20 ft. or more in diameter. Annual capacity is rated at about 2,762,000 tons or more than the total electric arc furnace capacity in the United States in 1940.

Mr. O'Mara noted that much effort has been concentrated on increasing production rates and furnace efficiencies. According to him, people feel that the maximum power of the electric furnace is limited by refractory life, and that 35,000 kva. is about the practical limit of power input. Furnace economic status, production capacity and transformer loading is determined by the melting period and the character of the charge. During this period, the highest available voltages are used to achieve the most rapid meltdown by developing the highest current densities throughout the longest arcs and the charge.

All the furnaces are operated to produce steel at a rate which exceeds their "rated" capacity by at least 20% – and some are pushed at the highest possible rate every possible minute. This imposes a continual high loading of electrical equipment as well as mechanical and refractory equipment. Heat times vary from 3½ to 7 hr. depending on the melting practice used, the type of charge, the final product, and so forth. It is an operation in which apparently every means possible must be used

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Circle 1408 on Page 48-A

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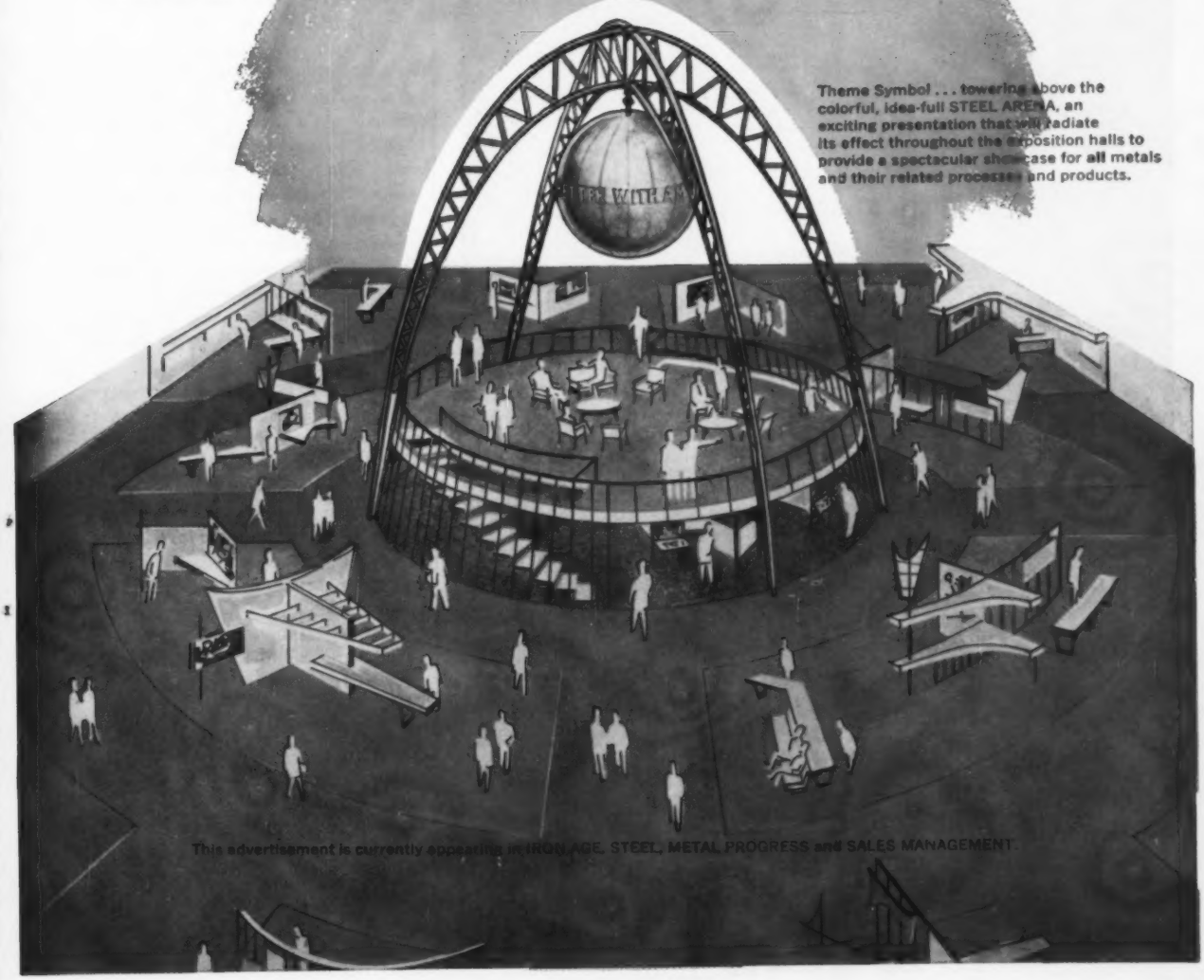

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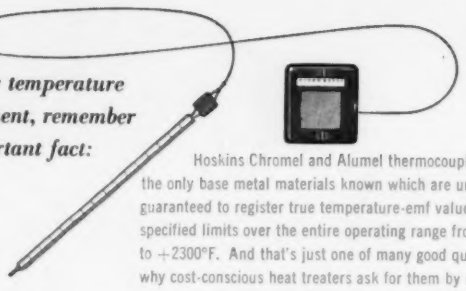
This advertisement is currently appearing in IRON AGE, STEEL, METAL PROGRESS and SALES MANAGEMENT

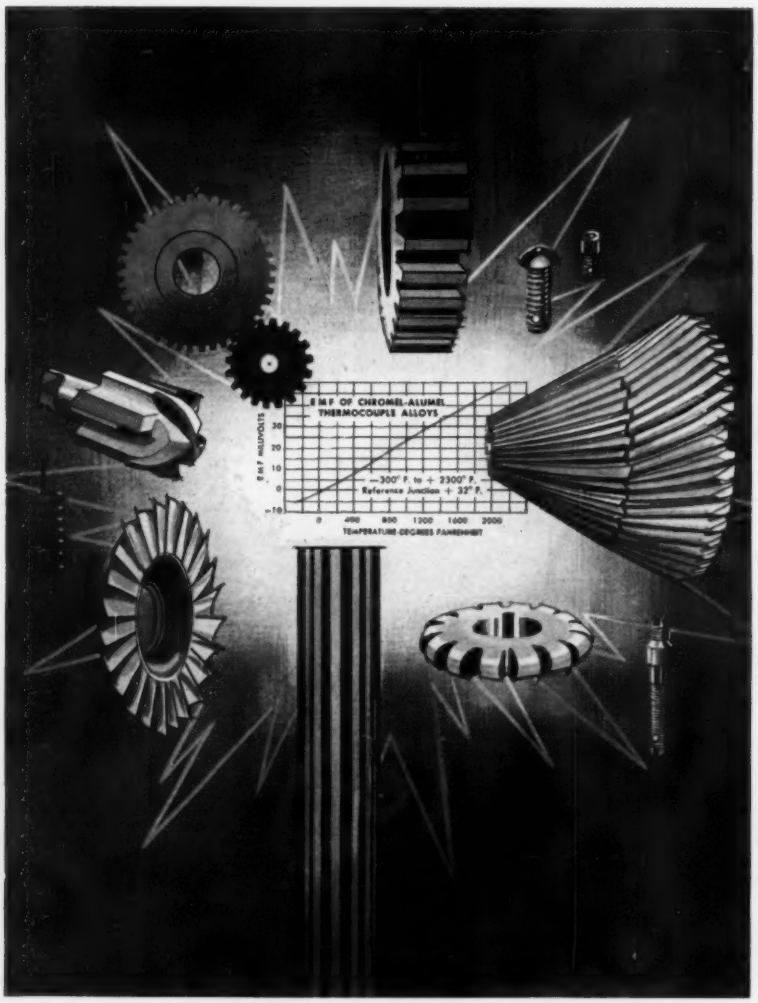
When you buy temperature control equipment, remember this very important fact:



Hoskins Chromel and Alumel thermocouple alloys are the only base metal materials known which are unconditionally guaranteed to register true temperature-emf values within close specified limits over the entire operating range from −300°F. to +2300°F. And that's just one of many good quality reasons why cost-conscious heat treaters ask for them by name . . .

Chromel®-Alumel®*

THERMOCOUPLE ALLOYS



Available through instrument manufacturers, thermocouple fabricators, and pyrometer service companies. Write for complete technical data.

**Trade names you can trust for accurate temperature measurement!*

Genuine Chromel and Alumel are produced exclusively by

HOSKINS MANUFACTURING CO.

4441 Lawton Avenue • Detroit 8, Michigan

Custom Quality resistance, resistor and thermo-electric alloys since 1908

Circle 1409 on Page 48-A

Electric Steel . . .

to insure the shortest time in producing a heat. This time is affected by layout, practice used, scrap type, maintenance practice, and many other factors. Apparently relatively high efficiency levels have been maintained even with important increases in power loads. Cold scrap is universally used, and oxygen is used in some instances to help clean the banks and speed up meltdown.

Hot metal is noted as having been used on a trial basis with promising results. Apparently not much data has been developed as to what hot metal really means and how it can best be used. He does note that with the use of only 25% hot metal in the charge the heat time might be reduced by as much as 15%, the tons per hour increased by the same amount, and the electrode and power consumption also decreased by about 15%.

The use of fuel-type roof and side-wall burners (which use oxygen enriched blast) is also mentioned. In one series of tests they helped to reduce heat times by almost 1 hr. Many efforts are being made to decrease heat times by increasing input power, directly reduced metallic charge, special preheating of the charge, and other methods. These efforts should eventually result in greatly increased performance from the large electric arc furnace.

Mr. O'Mara gave as a summary nine fields of activity which must be carefully investigated to obtain the maximum improvement in output from a modern tonnage electric arc furnace. If this is done, an important increase in the production of steel from electric-arc high-tonnage furnaces is still possible. These factors are:

1. Shop layout
2. Scrap handling
3. Scrap classification
4. High power input
5. Efficient use of high power
6. Electrode handling and assembly practice
7. Hot metal
8. Tonnage oxygen
9. Auxiliary gas burning with oxygen

Of these, it seems to me that the most important and logical factor on which to concentrate for an im-

If you are looking for

HEAT RESISTANT

A.C.I.

HA, HC, HD, HE, HF, HH, HI, HK, HL, HN, HT, HU, HW, HX

STAINLESS

A.C.I.

CA-15, CA-40, CB-30, CC-50, CE-30, CF-8, CF-20, CF-8M, CF-12M, CF-8C, CF-16F, CH-20, CK-20

Castings

LOOK NO FURTHER THAN fahralloy

For over a quarter of a century Fahralloy has served the needs of the nation's leading industries with highest quality alloy castings. Whether your particular need is for heat resistant alloy castings or stainless, you can be sure they'll be made to your exact specifications when you place your order with Fahralloy.

- TUBES
- TRAYS
- RETORTS
- BASKETS
- FIXTURES
- SOLUTION POTS
- CONVEYOR BELTS

ALLOY CASTING INSTITUTE ACI MEMBER

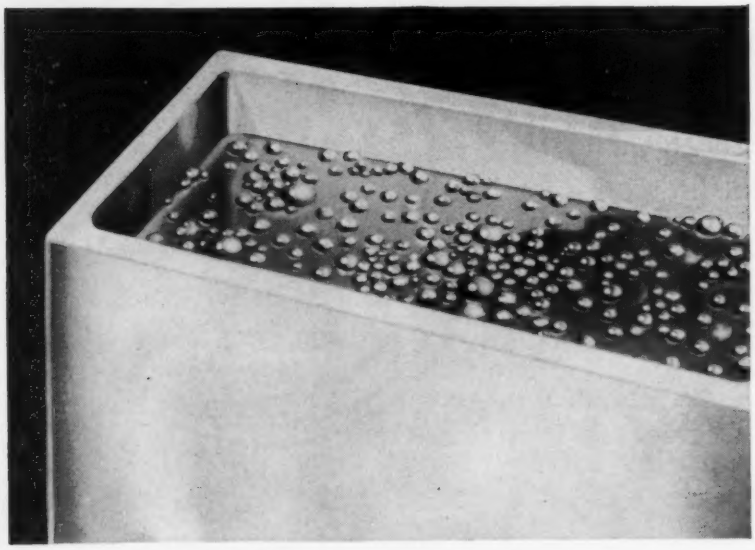
the fahralloy co.

150TH AND LEXINGTON AVENUE • HARVEY, ILLINOIS

QUALITY • SERVICE • INTEGRITY

Circle 1410 on Page 48-A

ACOUSTICA ULTRASONIC CLEANING REPLACES OLDER METHODS!



Texas Instruments, Martin Company, Bell Telephone Laboratories and many other firms are turning to Acoustica for better cleaning ultrasonically!

Now you can clean better and faster. In seconds—all dirt, dust, and soils are "cavitated" away ultrasonically. No scrubbing, no disassembling, maintenance costs are sharply reduced. Acoustica ultrasonic systems are application tested and *certified* for your particular needs. Send for details of complete Acoustica line of the most advanced ultrasonic equipment and cleaning chemicals. Acoustica Associates, Inc., Fairchild Court, Plainview, N. Y., 10400 Aviation Blvd., Los Angeles, Calif.

CERTIFIED APPLICATIONS

acoustica

ULTRASONIC CLEANING SYSTEMS

Circle 1411 on Page 48-A

Electric Steel . . .

portant increase in capacity at this time would be that designed to supply the arc furnace with an already more cheaply melted, low-silicon, low-sulphur charge of hot metal.

This might involve the building of an efficient unit for externally desiliconizing and desulphurizing blast furnace hot metal. It would relieve the arc furnace from the melting load, and its high cost for power and wear and tear on the furnace. The arc furnace would be used primarily to reduce carbon and remove phosphorus in a really active bath which would go far to insure uniform temperature and extra clean steel. Such a unit would be similar to one recently developed which is designed for the "external treatment of hot metal to remove sulphur, silicon, . . . at a high rate".

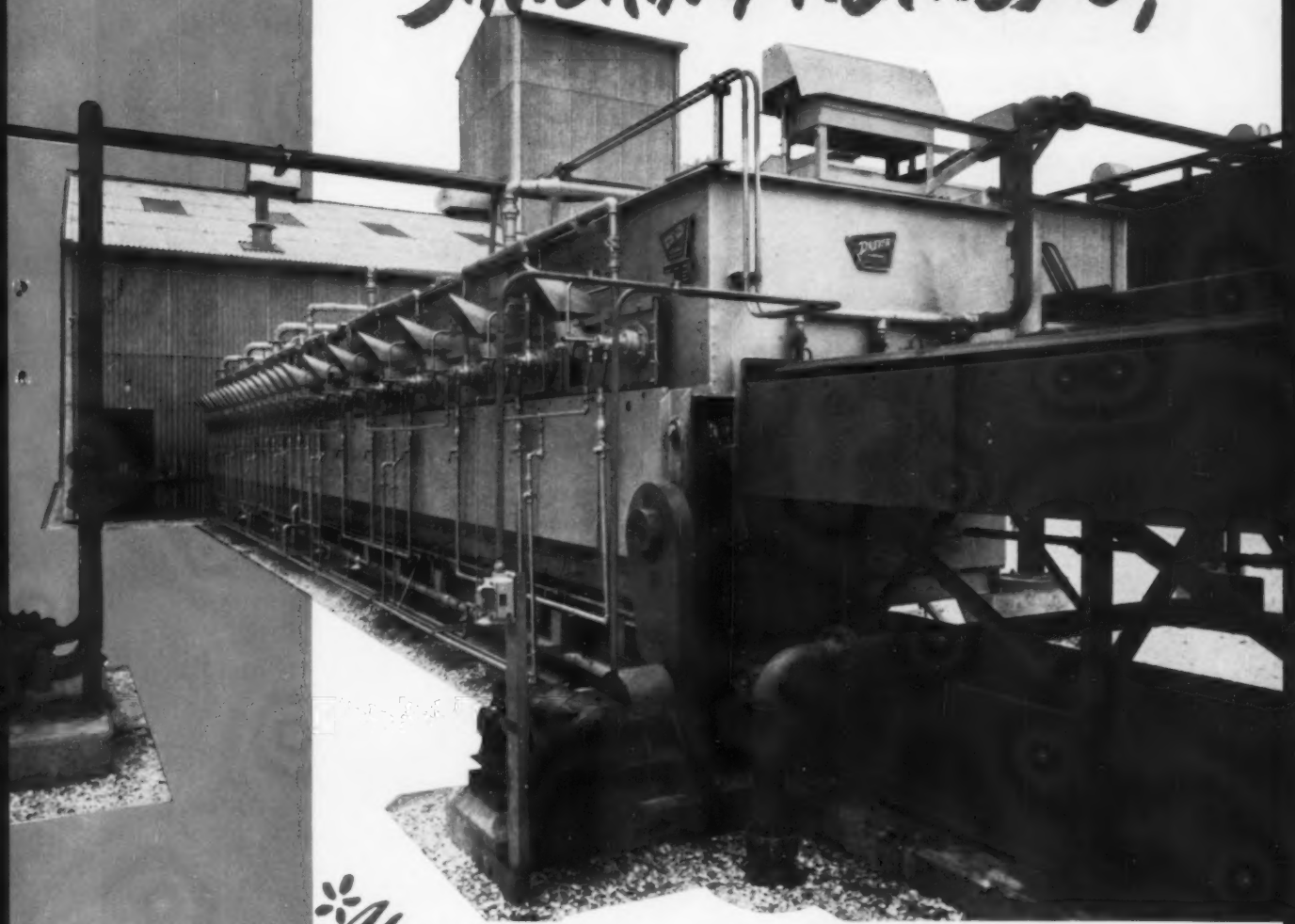
If the steel industry would concentrate its engineering efforts to produce a continuous fuel-fired concentrated iron ore melting unit which utilized added oxygen to develop the necessary temperature at the rate desired (along with powdered coal to remove the oxygen from the molten ore), the steel melting furnace would soon become independent of the blast furnace. If the external reduction unit was used to reduce silicon and sulphur to very low limits in the hot metal so produced, the whole production of electric furnace steel directly from the treated hot metal might very easily become economically superior to any other known method of steel production.

H. W. McQuaid

THE METAL THORIUM

A unified collection of detailed information on both the fundamental scientific and the technological and engineering aspects of thorium. For designers, metallurgists, researchers, students and workers in nuclear engineering and science. Supervised by Dr. H. A. Wilhelm — 397 pages — 6 x 9 — illustrated — red cloth cover — $10.00. Clip and send to ASM Technical and Engineering Book Information Service, Metals Park, Novelty, Ohio.

SINTERING AL FRESCO!



Yes, OUT-OF-DOORS! Here's a Drever Furnace installation for sintering nickel briquettes at the plant of the Freeport Nickel Company, Port Nickel, Louisiana. Its outdoor setup eliminates the need for costly building space—but this is only one of its interesting features.

HIGH LOAD CAPACITY—AUTOMATED OPERATION

Built to handle continuous in-line 8800# per hour production of sintered nickel briquettes, this Drever Furnace combines the high loading capacity of a roller hearth with the material handling convenience of a conveyor belt furnace. It is a radiant-tube, natural gas fired, roller hearth type furnace, gas tight for controlled atmosphere operation.

NO TRAY LOADING OR UNLOADING

Material passes through the furnace on a continuous mesh belt which allows greater circulation of heat and gas for uniform production and eliminates the need for trays. Automatic handling equipment loads briquettes onto the belt and conveys the sintered briquettes from the end of the furnace for weighing and packaging.

DREVER ENGINEERING FOR YOU

This unique out-of-doors installation is an example of Drever application of sound engineering principles, and experience in the field of furnace design. Our engineering staff is available for consultation concerning your requirement—write or phone us. Drever Company, Bethayres, Pa. Phone: WIlson 7-3400.

DREVER INDUSTRIAL FURNACES

ENGINEERED TO YOUR PARTICULAR REQUIREMENTS

ENGINEERING AND MANUFACTURING FACILITIES AROUND THE WORLD THROUGH ASSOCIATES IN FRANCE, GREAT BRITAIN, GERMANY, ITALY AND JAPAN

Circle 1424 on Page 48-A

NOW...full-time analysis of materials in actual production

XEG X-Ray Emission Gage watches and measures up to 5 selected elements

Solids, powders, slurries, fluids — General Electric XEG X-Ray Emission Gage examines them as they actually move through production . . . writes a running record of their elemental make-up. XEG tirelessly surveys up to five elements simultaneously, continuously . . . senses both their *presence* and *quantity*. Where practical to operate minus reference, even analyzes a sixth element.

Versatile XEG serves equally well for on-line process control or individual-sample analysis. Scientifically trained operator is not required — because once set for specific analysis, there's little need for further adjustment. XEG then automatically delivers the facts on composition for rapid-fire, continuous feedback to process control.

Applications are as limitless as your imagination. And, whenever you like, we can explore XEG potentials with you. The details are available now from your G-E x-ray representative. Or write us at General Electric Company, X-Ray Department, Milwaukee 1, Wisconsin, for Pub. AS-44.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 1366 on Page 48-A

METALGRAMS

. . . news about metals and metal chemicals

UNION CARBIDE METALS

Electromet brand ferroalloys, pure metals and metal chemicals

MARCH - APRIL, 1960

Sub-micron Tungsten Powder -- Ultra-fine tungsten powder with particle size in the 0.015 to 0.030 micron range is a recent product of UCM research. Uses are proposed in powder metallurgy, dispersion hardening, and catalysis. This highly flowable powder has closely dimensioned, spherical particles; measured surface area is in the range of 10 to 20 sq. m. per gm. UCM's field representatives are available to discuss new applications. For properties request WPI-P6.

* * *

Columbium Alloy Readily Fabricated -- A new medium-strength columbium-base alloy -- CB-65 -- which has an ultimate tensile strength of 37,000 psi at 1800°F. was announced by UCM. This alloy, containing titanium and zirconium, can be cold rolled extensively and also retains a high degree of notch-toughness at sub-zero temperatures. These properties indicate that the alloy is ductile and should exhibit good formability. The material is now available on a development scale. Properties of CB-65 are given in data sheet CBA1-P6. free on request.

* * *

40,000 psi at 2200 F -- Tensile strengths in excess of 40,000 psi at 2200°F are indicated by preliminary data on CB-7, a member of UCM's family of columbium-base alloys. Recent tests also indicate that CB-7 has a high degree of oxidation resistance when compared to other columbium alloys presently known. The alloy has been developed for applications in the 2000°F plus range for both sheet and forgings. The Company anticipates that limited quantities of the CB-7 alloy will be available for test purposes. For properties data request CBA2-P6.

* * *

Higher Yield Indicated With Activated Catalyst -- High yield, high isotactic crystallinity, and a clear polymer are indicated by laboratory test of UCM's activated titanium trichloride. Delving into the problem of activation, the Company's researchers are designing this modified form of titanium trichloride -- designated $TiCl_3$-1A -- especially for polypropylene catalysis. The unactivated product, $TiCl_3$-1, is also being evaluated in catalysis as well as in several other uses -- organometallic synthesis, reducing agent for organic nitro compounds, and special pigment. Data on titanium trichlorides are available in Bulletin TT2-P6.

* * *

Vanadium Mill Products Growing -- One of the largest vanadium shape orders to date -- 300 lbs. of bar, sheet, and plate -- was delivered by UCM in February. The material, earmarked for Government use, represents another important stride toward commercial availability of vanadium mill products. UCM has made bar and wire in sizes down to 0.005 in. diam. and plate and sheet down to 0.005 in. thick in widths up to 18 in. Bulletin VM1-P6 gives general information on vanadium.

* * *

Hard, Oxidation-Resistant Coatings -- UCM's chromium carbide, titanium carbide, tungsten carbide, and chromium boride are being used or evaluated in coating applications. Applied by metallizing or flame spraying methods, pure or combined with metal binders, these compounds provide coatings which have high hardness and oxidation resistance. UCM sales representatives are exploring coating requirements with potential users. Data packet IM1-P6 gives properties of materials.

* * *

Union Carbide Metals Company, Division of Union Carbide Corporation, 30-20 Thomson Avenue, Long Island City 1, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

"Electromet" and "Union Carbide" are registered trade marks of Union Carbide Corporation

Circle 1374 on Page 48-A

HERE'S THE LATEST WORD ON COOLER GRINDING—

New COOLTEX by Texaco!

New Cooltex keeps machines cleaner, lets dirt and grit settle out faster. This means *freer, cooler grinding—without heat checks*—for smoother finishes. With Cooltex, wheels last longer, and you can even use a finer grit! Your Texaco Lube Engineer is sending out Cooltex reminder postcards. Watch for yours. Texaco Inc., 135 East 42nd Street, New York 17, N. Y.

Tune In: Texaco Huntley-Brinkley Report, Monday through Friday—NBC-TV.

TEXACO

Throughout the United States
Canada • Latin America • West Africa

Circle 1427 on Page 48-A

From a small furnace to a tall furnace Hevi-Duty helps you find the value solution to your heat treating problems

Each of the Hevi-Duty furnaces shown below delivers the value solution to a heat treating problem—the solution combining comprehensive design and industrial engineering with soundly built and tested equipment—the solution that pays off in increased production and extended economic life of equipment.

In each case, Hevi-Duty drew from its experience in solving thousands of industrial heat processing problems for all types of applications.

In each case, Hevi-Duty offered equipment from industry's most complete line of electric and fuel-fired furnaces and ovens. (Where stock designs or adaptions won't do, Hevi-Duty custom-engineers equipment—from laboratory furnaces to huge field-assembled furnaces.)

Case histories by the hundreds testify that it makes profitable sense to call in your Hevi-Duty sales engineer to help find the value solution to your heat treating problems.

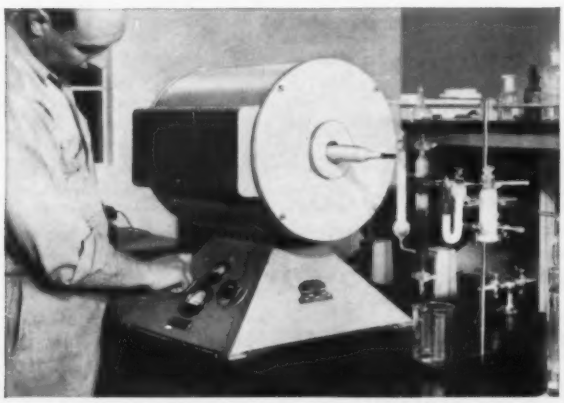
HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

B P C — A Division of Basic Products Corporation

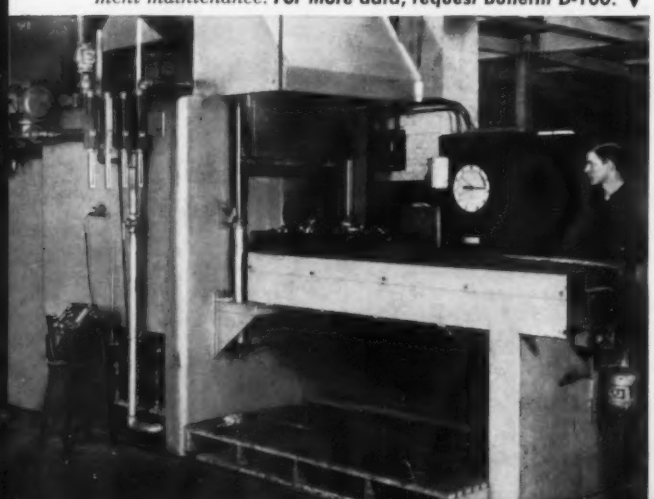
Hevi-Duty Electric Company, Milwaukee 1, Wis.

Circle 1428 on Page 48-A

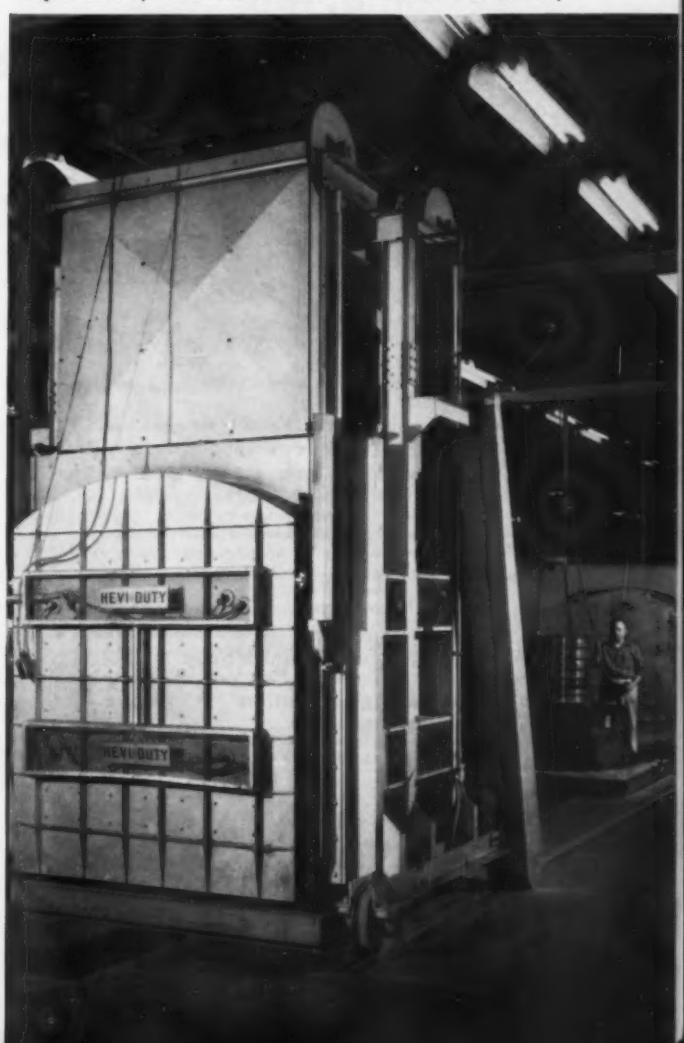


▲ *Merit Corp., Milwaukee, Wis., uses a Hevi-Duty tube furnace to maintain precise temperatures in laboratory quality tests on briquettes used by foundries as an additive to gray iron melts. Two-stage combustion operation on crushed sample burns off free carbon at 1679°F, total carbon at 2471°F.* **For more complete information, please write for Bulletin 254.**

Superior Metal Treating Corp., Muncie, Ind., uses two Hevi-Duty automatic Clean-Line furnaces 24 hours a day, 5 days a week for carburizing, carbonitriding and bright hardening. Temperatures range to 1925°F. The load-transfer mechanism is outside the heating chamber, reducing equipment maintenance. **For more data, request Bulletin D-100.** ▼



This Hevi-Duty traveling, double-end, box furnace provides ±10°F control at temperatures to 1850°F for bright tempering and stress relieving stainless steel jet engine weldments. This furnace is in continuous operation. User reports brightness improves during process. Unit provides bell-furnace mobility despite lack of head room. **Please write for Bulletin 653.** ▼



The Metals Engineering Institute

Educational division of ASM

ANNOUNCES

a new home study course . . .

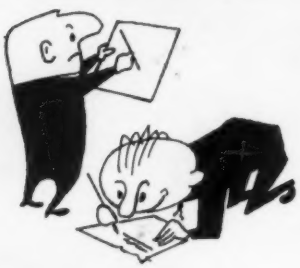
PRINCIPLES OF MACHINING

Do you know how to select the proper tool for the job?

Lesson 4. The Cutting Tool, will teach you.

Do you want to save money on tools?

Lesson 6. Tool Life, Measurement and Control, will tell you.



Do you want to bid lower, make a greater profit on your next job?

Lesson 9. The Economics of Machining, will tell you how.

This new course is a MUST for all machine shop owners, foremen, plant superintendents and those who want to understand machining and get ahead in their present job.

Be sure to read the full description of the course and its 15 informative and fascinating lessons on the next page.

William R. Backer, MSc, author of PRINCIPLES OF MACHINING.

Mr. Backer is a graduate of Rensselaer Polytechnic Institute, where he received a bachelor's degree in mechanical engineering. At Massachusetts Institute of Technology he obtained a Master of Science degree, and did research in metal cutting. Since then he has been employed in research and development activities, principally in the field of grinding and machining. After gaining experience with Linde Air Products Company and Boeing Airplane Company, he became Senior Research Engineer at the Cincinnati Milling Machine Co., with responsibility for the program on basic metal processing research. Recently he was appointed Machine Research Engineer of Norton Co., with research and development responsibilities in the Grinding Machine Division.

He has been active in metal processing research for the national organization of the A. S. M. E., and has published articles and lectured on topics concerning fundamental metal cutting theory.

METALS ENGINEERING INSTITUTE
Metals Park, Novelty, Ohio
Please send me information on Course B,
PRINCIPLES OF MACHINING

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Address_____

City_____

Company_____ Job or Title_____

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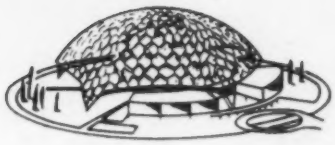
METALS PARK, NOVELTY, OHIO

PRINCIPLES OF MACHINING

(Course No. 8)

a new home study course from
Metals Engineering Institute



15 Informative, Important Lessons

1 The Machine Tool—basic machining processes—machine tool structure, motions, and drives—cutting tools—jigs and fixtures—machine tool selection.

2 What Happens When Metal is Cut—how chips are formed—chip types—chip formation processes—shear and rake angles—cutting ratio—forces acting on a cutting tool—shearing and friction processes—force measurements.

3 Effects of the Cutting Process—causes of good and poor surface finish—control of surface finish—nature, extent, effects, and control of hardening produced by cutting—sources, measurement, and control of heat in the cutting process—mechanism, nature, and control of tool wear—vibrations and chatter.

4 Cutting Tools—rake angles and inclination—relief and clearance—interrupted cuts—chip breaking—cutting tool materials—high speed steel—cast alloys—sintered carbides—oxides.

5 Force, Work and Power in Machining—gross and net power—power measurements—specific power consumption—metal removal factor—effects of cutting speed, cut dimensions, rake angle, tool material, cutting fluid, and workpiece material—power nomographs and calculators—metal removal rate—power and forces in grinding.

6 Tool Life—Measurement and Control—definitions, mechanisms, and criteria of tool failure—tool life testing—effects of cutting speed and cut dimensions—tool life in grinding.

7 Machinability of Metals—specification of machinability—simple tests—cutting ratio—ratings—relation to hardness, tensile properties, composition, microstructure, and work hardening ability—grindability.

8 Machinability Versus Microstructure—structure of metals—phase diagrams—microstructure of iron and steel—hardness of microconstituents—machinability versus microstructure in plain carbon steel, alloy steels, stainless steels, high temperature alloys, cast iron, and nonferrous alloys.

9 The Economics of Machining—idle, metal cutting, tool changing, and tool reconditioning costs—optimum machining conditions—cutting speed for minimum cost—economic versus productive cutting speed—reducing machining costs—computing aids.

10 Cutting Fluids—gases, oils, and water-base fluids—cooling and friction reducing action—cutting fluid application, selection and economics.

11 Surface Quality—specification, measurement and control of surface finish causes of poor finish—effects of machining process, machine settings, feed, workpiece and cutting fluid—grinding burn—residual stresses in grinding.

12 Turning—characteristics of turning—engine, turret and automatic lathes—boring machines—single point tools—machine and tool design—cutting forces, power consumption, and tool life—turning economics—current trends.

13 Milling—milling characteristics—knee and column, bed type, and special milling machines—attachments—milling cutter nomenclature—cutter angles, classes and materials—number of teeth—up and down milling—power, forces, tool life and surface finish—current milling trends.

14 Drilling—characteristics and relation to other processes—vertical, radial, horizontal, production, and special drilling machine—drill nomenclature and classification—drill materials—point angles—machine and fixture design—torque and power—thrust—tool life—current trends.

15 Grinding—the grinding process—surface, cylindrical, internal, tool and cutter, and special grinding machines—grinding wheel nomenclature—abrasives—bonds—wheel selection—balancing, truing, and dressing—wheel wear-grinding fluids—economics—current grinding trends.

Write for information on PRINCIPLES OF MACHINING or any of these 21 other popular courses:

1. Elements of Metallurgy
2. Survey of Steel Plant Processes
3. Iron Blast Furnace Operations
7. Metals for Nuclear Power
10. Heat Treatment of Steel
11. Fundamentals of Ferrous Metallurgy
14. Corrosion
16. High Temperature Metals
18. Stainless Steels
19. Tool Steels
22. Electroplating and Metal Finishing
24. Magnesium
25. Copper, Brass and Bronze
27. Titanium
30. Primary and Secondary Recovery of Lead and Zinc
31. Steel Foundry Practice
33. Gray Iron Foundry Practice
37. Fundamentals of Welding and Joining
38. Oxy-Acetylene Welding
39. Arc Welding
41. Principles of Heat Treating

What is Metals Engineering Institute?

MEI was set up by the American Society for Metals at the insistence of its membership and industry to provide much-needed training in metal theory, heat treatment, metal fabrication, etc. MEI is a non-profit organization and an accredited member of the National Home Study Council. MEI is under the direction of Dr. Anton deS Brasunas. Courses are written by informed men, carefully chosen from industry and the teaching profession.

Who "goes" to MEI?

Technicians, salesmen, educators, plant owners, superintendents, foremen and production workers all take the same courses at home or sit in the same classes through MEI's highly successful in-plant training programs or classes organized by local ASM chapters throughout the United States and Canada.

What students say about MEI

"Thanks to your fine course I have taken over the job of my past supervisor."

"I am not an authority on education but I consider the MEI material that I have studied to be the equivalent to the same subjects given by an engineering college in its evening courses."

". . . it was in a large part due to my enrollment in two MEI courses that I was able to advance myself from a metallurgical technician to an engineer and find a new job at a greater rate of pay."

Write for information today!

METALS ENGINEERING INSTITUTE
METALS PARK, NOVELTY, OHIO

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Metals Park, Novelty, Ohio
Gentlemen: Please send me full information on the following courses:

_____

Name_____

Address_____

City_____

Company_____ Job or Title_____

KNOW YOUR ALLOY STEELS . . .
This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Quenching Media for Alloy Steels

In the quenching of alloy steels, several points require consideration, among them being the size and shape of the piece, the type of steel involved, the quenching medium, and proper agitation of the quenching bath.

The composition of the steel has an important bearing on the selection of a quenching medium. As an example: shallow-hardening steels require a fast cooling rate, whereas deeper-hardening steels require progressively slower rates as the alloy content increases.

Three commonly used types of quenching media for alloy steels are water, oil, and air. These are discussed below in the order of quenching severity:

(1) WATER. Since shallow-hardening steels require fast quenching rates, water is the quenching medium used to harden them. Agitation is generally used to help in obtaining the desired cooling rate. The use of brine solutions have proven beneficial when sufficient agitation cannot be obtained. It should be noted that the quenching rate drops as water temperature is increased. The range of 70 deg to 100 deg F is recommended.

(2) OIL. An oil quench cools more slowly than water, and faster than air. Oil-hardening steels can be hardened with less distortion and greater safety than water-hardening steels. Mineral oils are generally used because of their low cost and relatively stable nature.

(3) AIR. If sufficient alloying elements are present, critical cooling rates are decreased to the extent that certain steels can be quenched in either still or forced air.

While the choice of quenching medium is of prime importance, there is another factor that should not be overlooked. This is the agitation of the quenching bath. The more rapidly the bath is agitated, the more rapidly heat is removed from the steel, and the more effective the quench.

Bethlehem metallurgists will gladly help you with any problem related to quenching or other phases of heat-treatment. They are men of long practical experience in this field, and they understand fully the advantages and limitations of each method. Always feel free to call for their services; their time is yours, without obligation.

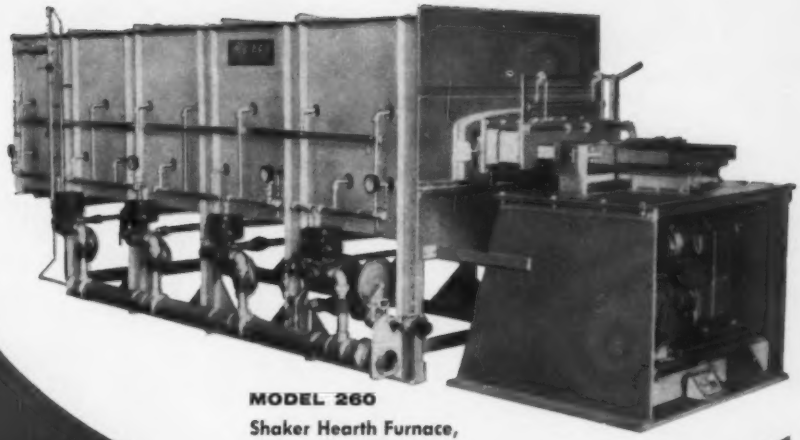
Remember Bethlehem, too, when you are next in the market for AISI standard alloy steels, special-analysis steels, or carbon grades. We are always in a position to meet your needs promptly.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Distributor: Bethlehem Steel Export Corporation

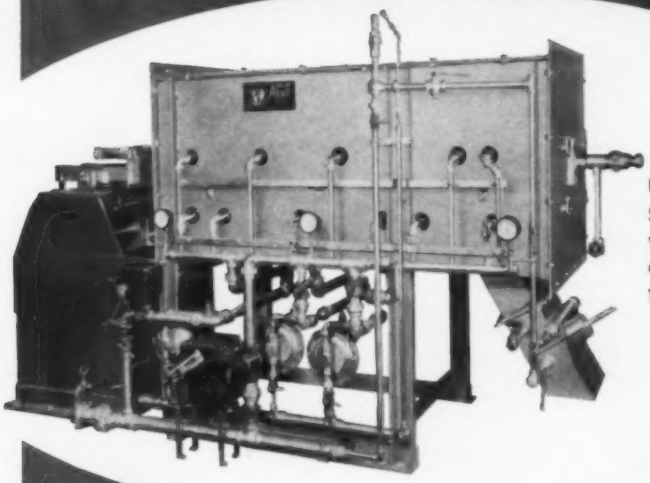
BETHLEHEM STEEL

Circle 1429 on Page 48-A

HEAT TREAT SMALL PARTS BEST with AGF'S SHAKER HEARTH FURNACES



MODEL 260
Shaker Hearth Furnace,
with a production
capacity of 800 lbs. per hour.



81 YEARS OF PIONEERING

MODEL 238-A
Shaker Hearth Furnace,
with a production capacity of
approximately
150 lbs. per hour.

VERSATILE Complete atmosphere control for heat treating from pen points to forgings, *IN THE SAME FURNACE.*

SIMPLE Complicated maintenance problems are eliminated by the unique method of work conveyance . . . A reciprocating hearth plus a simple mechanical drive.

EFFICIENT No conveyor to drag heat from furnace . . . A CONTINUOUS FURNACE for automatic or manual feeding.

FULL MUFFLE CONSTRUCTION Provides exact control of processing atmosphere . . . Many small burners, in multiple control zones, heat the muffle uniformly.

Shaker Hearths are available with capacities from 25 lbs. per hour to 800 lbs. per hour.

Send for complete data and specification sheets on these and all of the other many "QUALITY BUILT" AGF furnaces for all specific and diversified uses.

AMERICAN GAS FURNACE CO.
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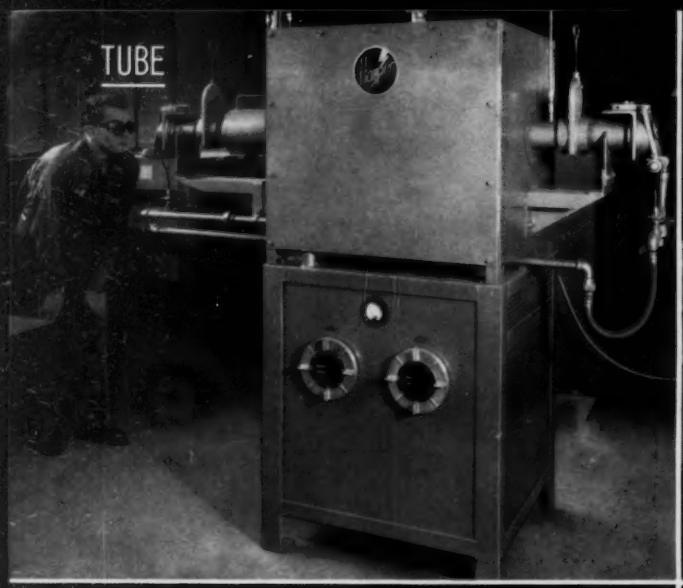

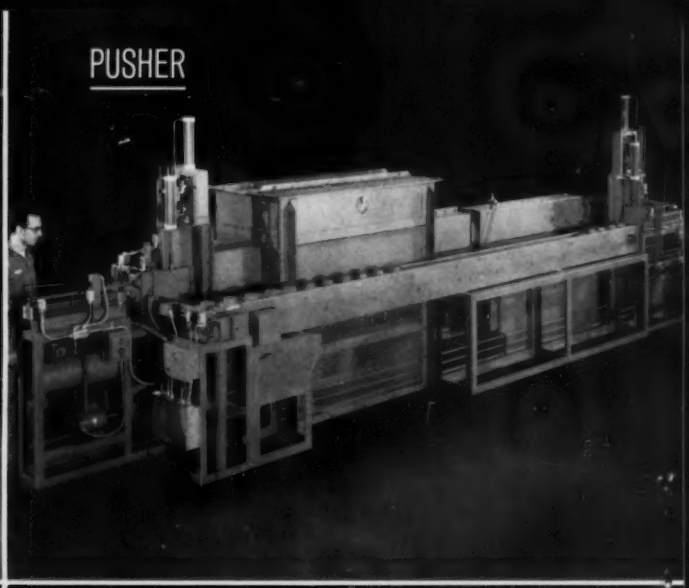

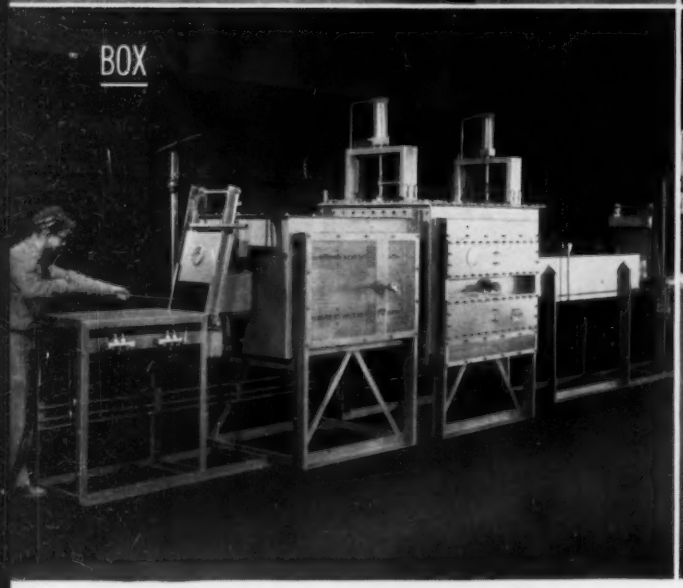

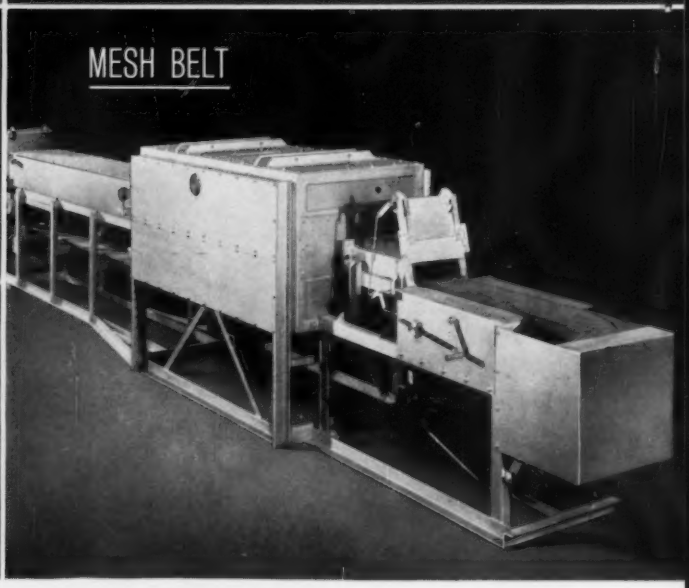

SINTERING FURNACES

all types to answer your powder metallurgy needs to best advantage

HARPER BUILDS THEM ALL: Box, pusher, mesh belt, roller hearth, bell, elevator and pit . . . for research, pilot plant and full scale production.

JUST NAME IT! No matter what the powdered metal — copper, brass, bronze, iron, iron graphite, tungsten or one of the stainless steels — Harper can supply the furnace that will do the sintering job most profitably for you. Furnished for manual and automatic operation, Harper electric furnaces are equipped with molybdenum, silicon carbide and nickel chromium alloy heating elements, as well as the proper refractories and controls, to match a diversified range of temperature and atmosphere requirements.

TAKE ADVANTAGE OF HARPER EXPERIENCE: The next time you are considering the addition or replacement of a sintering furnace, you'll find it pays to put it up to Harper early in the game — for Harper has the background to assist you in your planning. In the meantime, for more detailed information, write: Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

HARPER ELECTRIC FURNACES

FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH

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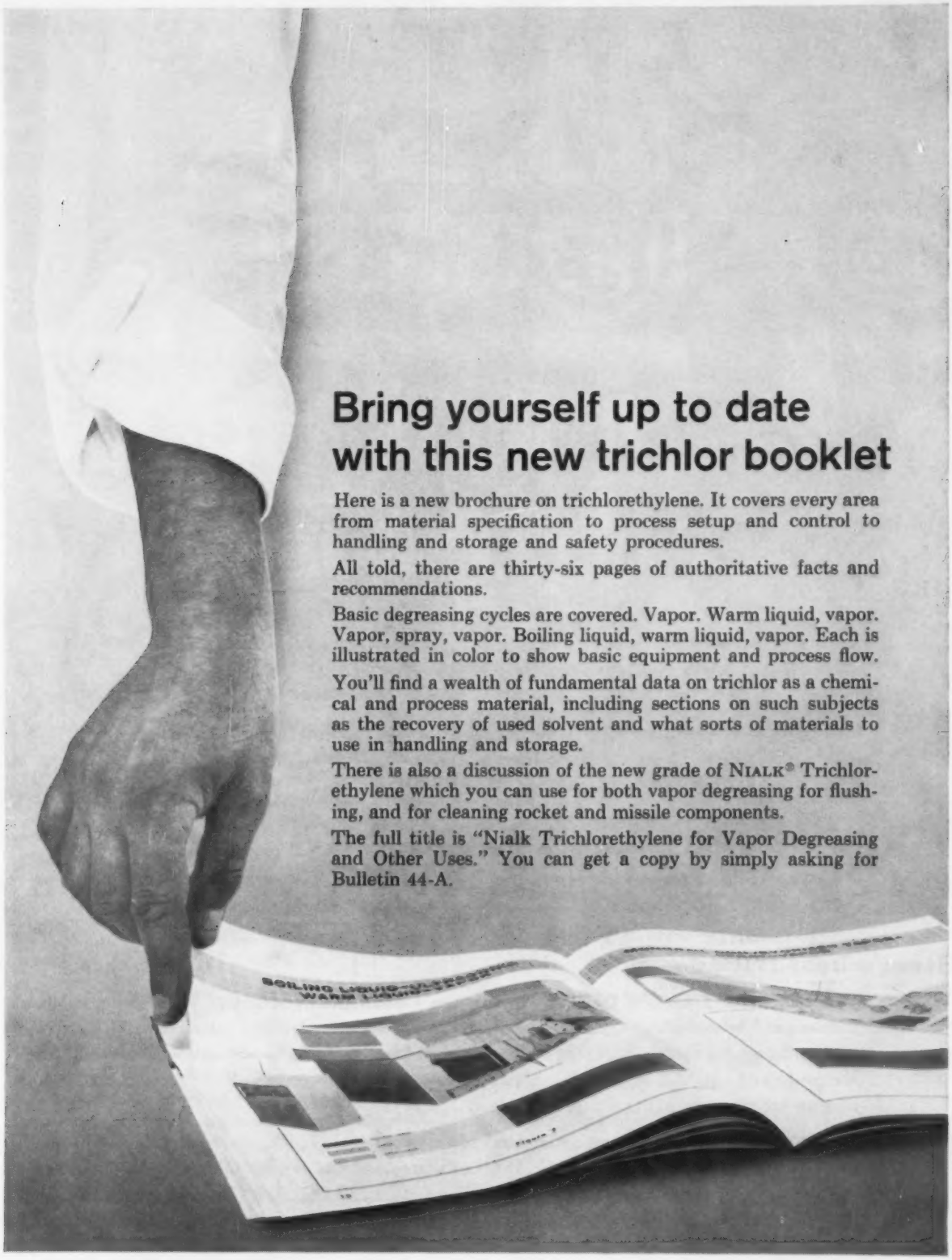

Bring yourself up to date with this new trichlor booklet

Here is a new brochure on trichlorethylene. It covers every area from material specification to process setup and control to handling and storage and safety procedures.

All told, there are thirty-six pages of authoritative facts and recommendations.

Basic degreasing cycles are covered. Vapor. Warm liquid, vapor. Vapor, spray, vapor. Boiling liquid, warm liquid, vapor. Each is illustrated in color to show basic equipment and process flow.

You'll find a wealth of fundamental data on trichlor as a chemical and process material, including sections on such subjects as the recovery of used solvent and what sorts of materials to use in handling and storage.

There is also a discussion of the new grade of NIALK® Trichlorethylene which you can use for both vapor degreasing for flushing, and for cleaning rocket and missile components.

The full title is "Nialk Trichlorethylene for Vapor Degreasing and Other Uses." You can get a copy by simply asking for Bulletin 44-A.

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4004 Union Street, Niagara Falls, New York
Sales Offices: Buffalo Chicago Detroit Los Angeles New York Niagara Falls Philadelphia Tacoma Worcester, Massachusetts
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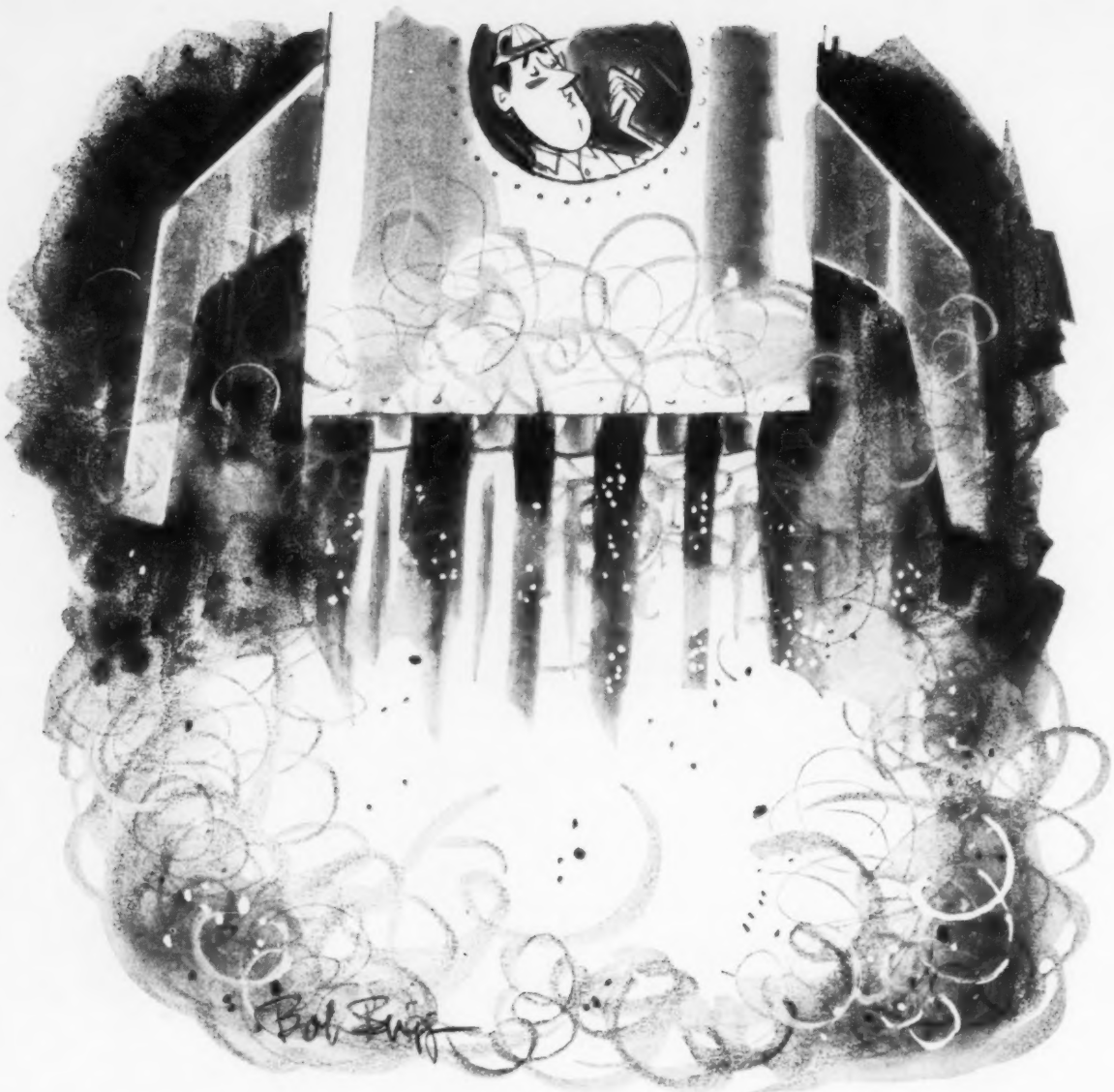
HOOKER CHEMICALS PLASTICS

Circle 1432 on Page 48-A



Steel's best friend

when the heat's on... *Vancoram Columbium Alloys!* High-quality stabilized stainless and heat-resistant steels perform best with an efficient alloy like columbium. VCA's special process for production of Vancoram Ferrocolumbium keeps undesirable elements at levels well within accepted standards. VCA supplies columbium in regular ferroalloy or in exothermic form, both of which have an exceptionally high columbium content.

THERMOCOL® (Exothermic Ferrocolumbium) saves you up to $7 a ton because of high columbium recovery and reduction in furnace time. It permits large amounts of alloy to be added with minimum temperature loss, and without contact between alloy and furnace slag. Write for more information about the special advantages offered by Vancoram Columbium Alloys. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y. · Chicago · Cleveland · Detroit · Pittsburgh

Be sure to visit our Booth (No. 1414) at the AFS Castings Congress, Philadelphia, May 9-13.

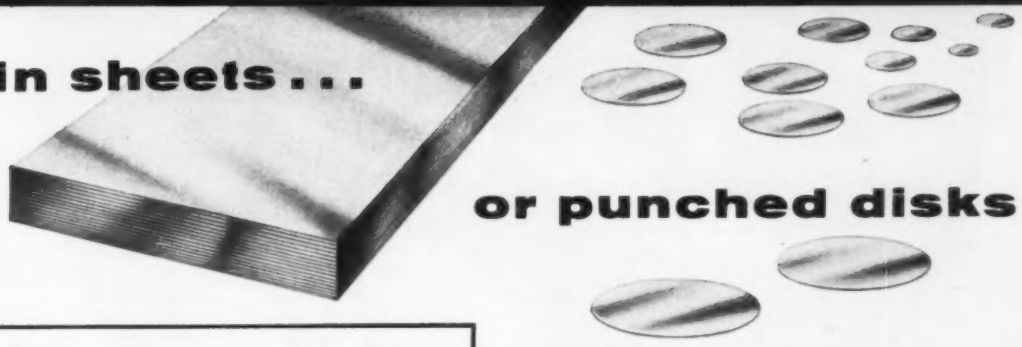
VANADIUM CORPORATION OF AMERICA

Producers of alloys, metals and chemicals

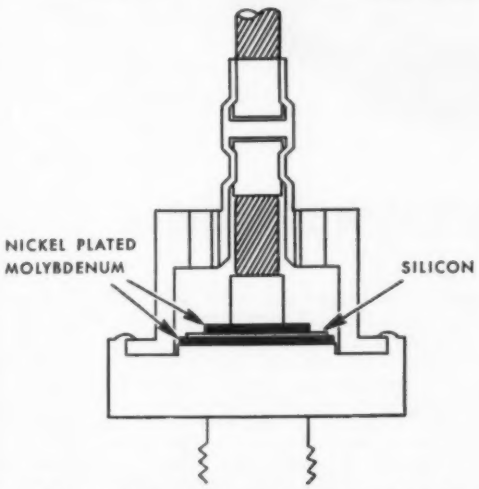
Circle 1433 on Page 48-A

Another New Fansteel Service

...NICKEL PLATED MOLYBDENUM



Ideal for Silicon Rectifiers



Fansteel nickel plated molybdenum provides these ideal qualities required in backing plates for silicon: (1) close match to silicon in coefficient of linear expansion, (2) low electrical resistivity, (3) good workability, (4) easily soldered and (5) low cost.

Fansteel's continuous program of new ideas, new products and new services now brings you famous Moly "D", *nickel-plated* for easier wetting in soldering operations. Nickel plated molybdenum promises particular advantages in such areas as backing plates in silicon rectifiers.

Because Fansteel molybdenum is plated with extreme care under strict quality control, the nickel plate has a tight adherence . . . will not flake or tend to separate in blanking operations . . . and provides excellent conductivity in electrical and thermal applications.

Moly "D" sheets can be supplied plated either on one side or both sides, and punched disks are available in a wide range of sizes.

For complete information, call or write your Fansteel representative or Fansteel direct . . . Metals and Fabrications Division.

FANSTEEL

FANSTEEL METALLURGICAL CORPORATION

NORTH CHICAGO, ILLINOIS, U.S.A.

K603

Circle 1434 on Page 48-A

Superior tubing makes pressures behave

whether 125, 5000, 30,000 or 100,000 psi

Superior small-diameter tubing makes pressures behave whether low, medium, high or super. Superior pressure tubing can be roughly divided into two groups: commercial pressure tubing for use in a range up to 20,000 psi; premium super pressure tubing to handle pressures from 15,000 to 100,000 psi. Both ranges can be handled effectively by a number of different analyses, depending on service requirements. Typical applications for Superior general-purpose pressure tubing include pressure tools, machine tools, heat exchangers and condensers. Superior super-pressure tubing is found in hydrogenation process equipment, high-pressure autoclaves, and pilot plant installations in chemical and oil refining plants.

All Superior pressure tubing offers many advantages. It helps prevent critical failures and downtime. It assures long service life, high fatigue strength, excellent corrosion and chemical resistance. In the range from 15,000 to 100,000 psi, Superior super-pressure tubing is a premium product. It is produced from specially selected raw materials. Inside surfaces are conditioned to remove fissures and other defects. During processing, special degreasing operations are performed, and the inside diameters are conditioned to insure a clear, smooth surface. Two types are available: a single wall mechanical tubing and a double wall, or composite unit, made from two thinner tubes. It is produced in an annealed condition and in ⅛ hard temper, and to mechanical properties specified by the customer. All Superior pressure tubing is 100% hydrostatically tested to recommended working pressures, and rigidly inspected for defects.

We can probably help you with any tubing problem that may confront you . . . in pressure, super-pressure or other applications. Contact us and feel no obligation. Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

Circle 1435 on Page 48-A

CARBORUNDUM'S TECHNICAL INFORMATION ON UNUSUAL REFRACTORIES **Data sheet**

How to choose materials for

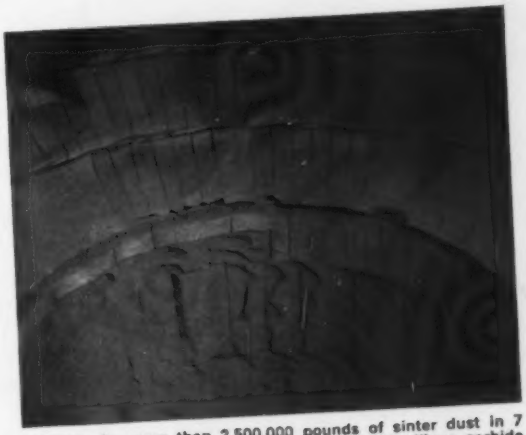
WEAR RESISTANCE

Choice of a material to give optimum wear resistance requires knowledge of type of wear (e.g. abrasion or erosion), effect on different materials, and presence of such factors as load, corrosion, thermal shock etc.

The two basic types of wear (examples shown at right) are (1) impingement of fine solids entrained in air, gas, or other fluid and (2) direct sliding of a solid mass across a surface. Effects may be erosion, primarily of the bond, thus dislodging the harder body granules; minute progressive bond fracture due to impact; or chipping, gouging or grinding of monolithic materials.

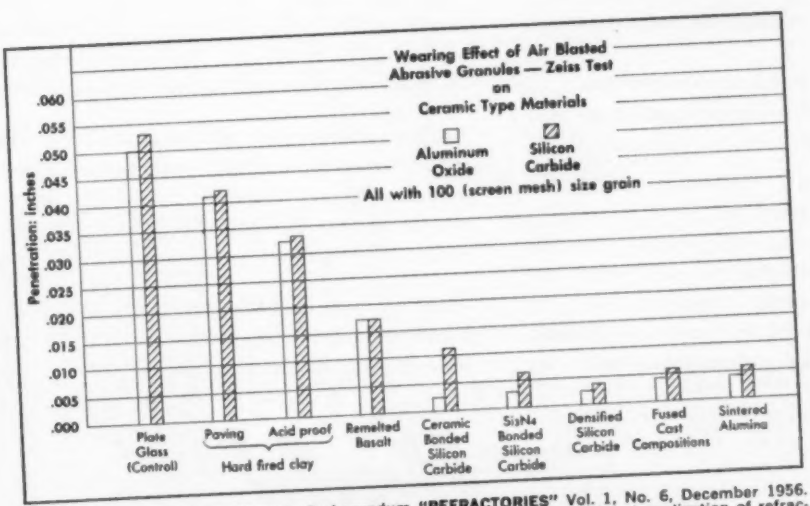
Refractories manufactured by Carborundum from electric furnace materials — such as silicon carbide and alumina — offer excellent wear resistance (see chart). Moreover, they are chemically inert, resistant to spalling, and have superior load-carrying capacity. As a result, they have found extensive use in dust collectors, gas scrubbers, transfer pipelines, hydro-cyclones, etc.

Carborundum's accumulated experience and data may help solve your wear problems. Feel free to ask for any assistance.



Abrasion by more than 2,500,000 pounds of sinter dust in 7 years has been resisted by the CARBOFRAX® silicon carbide lined cone of this primary dust collector. By comparison, other brick in the scroll and in the course between scroll and cone have been worn back to the shell, in one area after only 5 months.

Skids of CARBOFRAX® silicon carbide lasted 156 weeks under heat and the abrasion of 6¾" x 8" brass billets in this gas-fired extrusion mill furnace. Steel skids averaged only 5 weeks life.

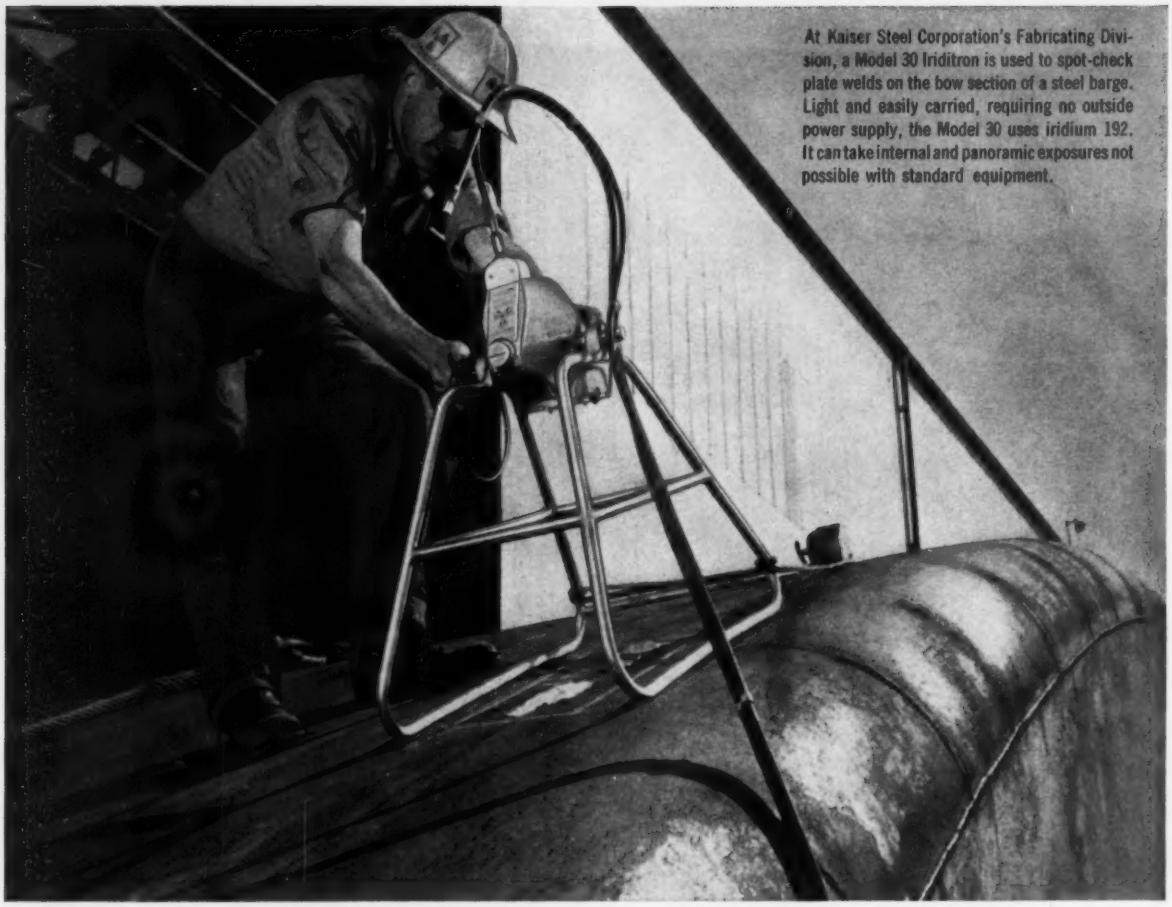


Information adapted from Chart 1, Carborundum **"REFRACTORIES"** Vol. 1, No. 6, December 1956. This bulletin, containing extensive technical information on the properties and application of refractory-type products, is published bi-monthly. Complimentary subscription on request.

Write today for your free copy of "Super Refractories by Carborundum." The address: Dept. M-40, Refractories Div., Perth Amboy, N. J.

For engineered refractories, count on **CARBORUNDUM®**

Circle 1436 on Page 48-A



At Kaiser Steel Corporation's Fabricating Division, a Model 30 Iriditron is used to spot-check plate welds on the bow section of a steel barge. Light and easily carried, requiring no outside power supply, the Model 30 uses iridium 192. It can take internal and panoramic exposures not possible with standard equipment.

Remote control of iridium... with Budd Iriditron units

- **Especially designed for remote handling of iridium 192**
- **Excellent for panoramic and internal exposure**
- **Permits exposure of iridium sources by remote control as far as 50 ft. away.**

Skid mounted or portable, this Budd Iriditron unit provides all the versatility of the traditional unshielded source for pipe weld radiography, panoramic exposure of multiple specimens, circumferential and longitudinal welds in boilers and pressure vessels. The unit can hold extremely strong sources . . . as much as 30 curies of iridium 192, approximately equivalent to a 260 KV X-Ray machine. This adds up to significant reductions in exposure times.

And you get complete service from Budd—including radioactive source supply and encapsulation, source replacement and disposal, training for your personnel (at no charge) and aid in setting up complete radioactive facilities.

Write or call Budd Instruments Division for our Gamma Radiography Bulletin . . . or for a consultation on your requirements.

INSTRUMENTS Budd DIVISION

THE BUDD COMPANY • P.O. Box 245 • Phoenixville, Pa.

Consult your phone book for sales offices in: Atlanta, Ga., Oak Park, Ill., Dallas, Tex., Los Angeles, Calif., San Francisco, Calif.
In Canada
Tatnall Measuring and Nuclear Systems, Ltd., 46 Hollinger Rd., Toronto 16, Ont.

Circle 1437 on Page 48-A

BERNARD S. LEMENT HAS WRITTEN FOR YOU . . .

DISTORTION IN TOOL STEELS

A NEW BOOK PUBLISHED BY AMERICAN SOCIETY FOR METALS

Distortion in Tool Steels is a practical, easy-to-read book exploring the size and shape changes in tool steels which occur during and after processing.

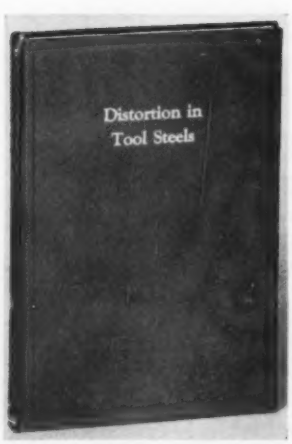
Readers will benefit greatly from the experience of its author. Dr. Lement's background includes both theoretical and practical work in this field and in this book he has sorted the most useful data yet assembled on this expensive problem to industry. His comprehensive knowledge has resulted in this first-of-its-kind book for metals and materials engineers, tool engineers, designers, heat treaters, machinists, mechanical engineers and inspectors.

Dr. Lement places particular emphasis on methods of heat treatment that are necessary for precise dimensional control. The problems encountered in the production of tool steel parts with extreme tolerances (cutting tools, dies, gages, ball bearings, valves, etc.) are treated in detail.

Also, how to prevent significant changes in finish dimensions during storage or under normal service conditions is discussed. How to minimize or eliminate costly finish machining operations by scientific dimensional control is thoroughly explored.

Tables, drawings, charts and graphs highlight the book's eight chapters:

1. CAUSES OF DISTORTION
2. MEASUREMENT OF DIMENSIONAL CHANGES
3. CALCULATION OF SIZE CHANGES
4. CONTROL OF DISTORTION
5. HARDENING
6. COLD TREATING
7. TEMPERING
8. AGING



If you are directly or indirectly related to the manufacture of tool steels or tool steel parts, *Distortion in Tool Steels* is a work of great importance. Dr. Lement writes to the men responsible for tool steel performance. His book represents an opportunity to become fully informed on size and shape changes in tool steels. Order your copy today.

ORDER WITH THIS COUPON

Distortion in Tool Steels—173 P.—8 chapters—illustrated—red cloth cover—6" x 9"—published by American Society for Metals—written by Dr. Bernard S. Lement—$10.00 per copy.

Please send me _____ copy(s) of *Distortion in Tool Steels*

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Enclosed find $_____ Or: Bill me ☐ Bill Company ☐

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Metals Park — Novelty, Ohio

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Economy

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HEATBATH CORPORATION

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38 Years of Service to the Heat Treating and Metal Finishing Industry

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NOW BASIC METALLURGY II

NEW COMPANION VOLUME TO FAMED BASIC METALLURGY I

This easy-to-read and practical book describes the equipment and its use for metallurgical operations. This is a practical guide to metallurgical equipment, test and techniques.

Well-illustrated with 67 pictures, 17 pull-out data sheets and 37 charts and graphs, Basic Metallurgy II contains a comprehensive 8-page index for handy use plus 68 references to other authoritative sources.

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HARDNESS TESTING
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THE **INDIUM** CORPORATION OF AMERICA
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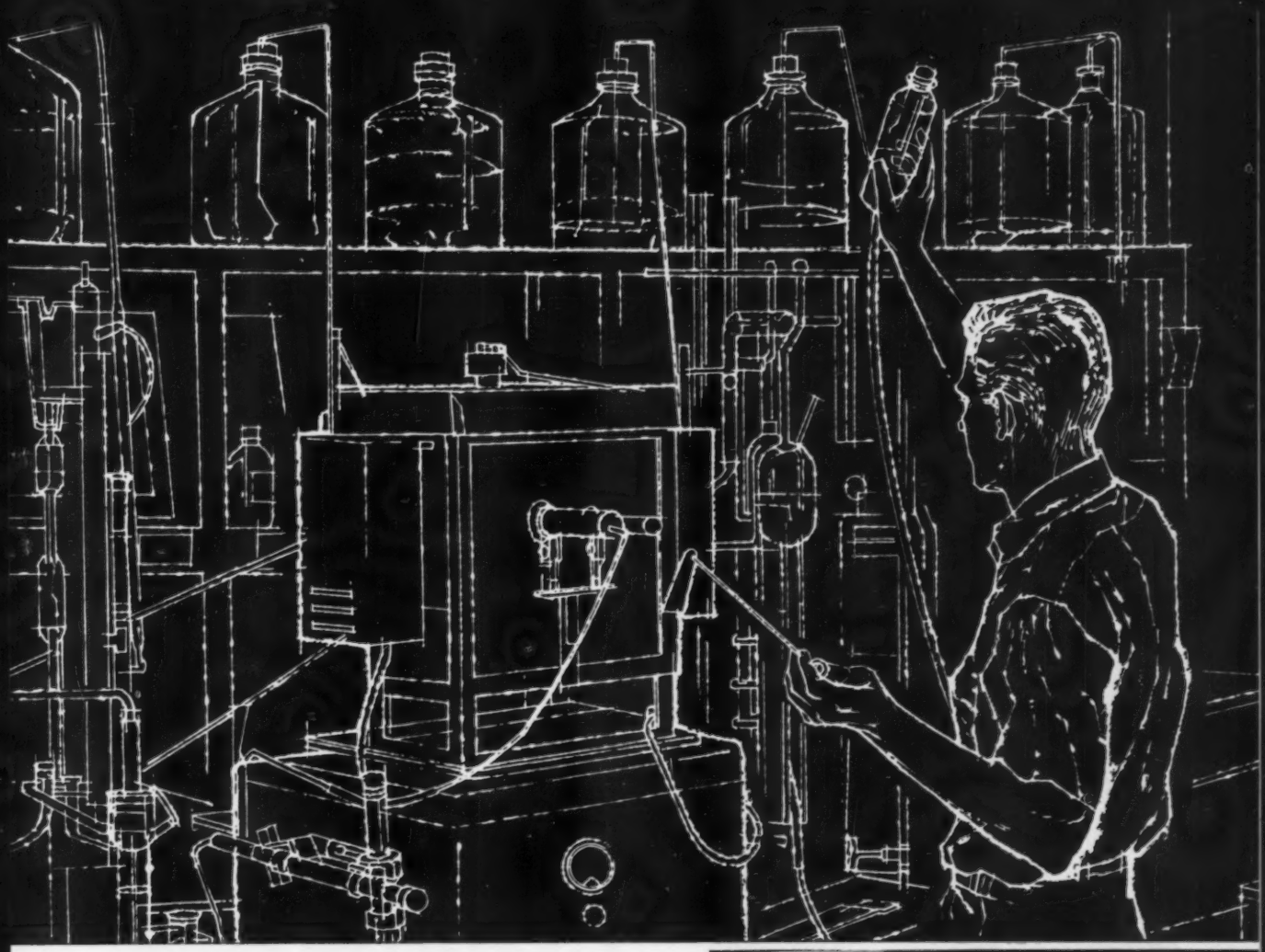

PRECISE ANALYSIS CONTROL

to your restricted specifications with

J&L Cold Rolled Strip Steels

Controlled analysis is one of the basic factors necessary for quality strip steels.

J&L offers you an experienced organization devoted to strip steel processing combined with fully integrated melting facilities designed for **controlled** analyses.

J&L's leadership in the use of basic oxygen furnaces, high standard open hearth practice and electric furnaces permits melting to more accurate analysis ranges than usually considered necessary. Above all, they assure cleanliness with residuals and inclusions held to a minimum.

With an organization experienced in specialized strip steel processing, your standard or most rigid specifications can be met consistently.

For your convenience, precision strip facilities are available to you in our plants at Youngstown, Indianapolis, Los Angeles and Kenilworth (N. J.)

J&L offers all three—basic oxygen converters, high standard open hearth practice and electric furnace melting to meet your **restricted specifications.**

J&L STRIP

LOW CARBON • HIGH CARBON • ALLOY • STAINLESS
TEMPERED SPRING STEEL • ZINC AND COPPER COATED

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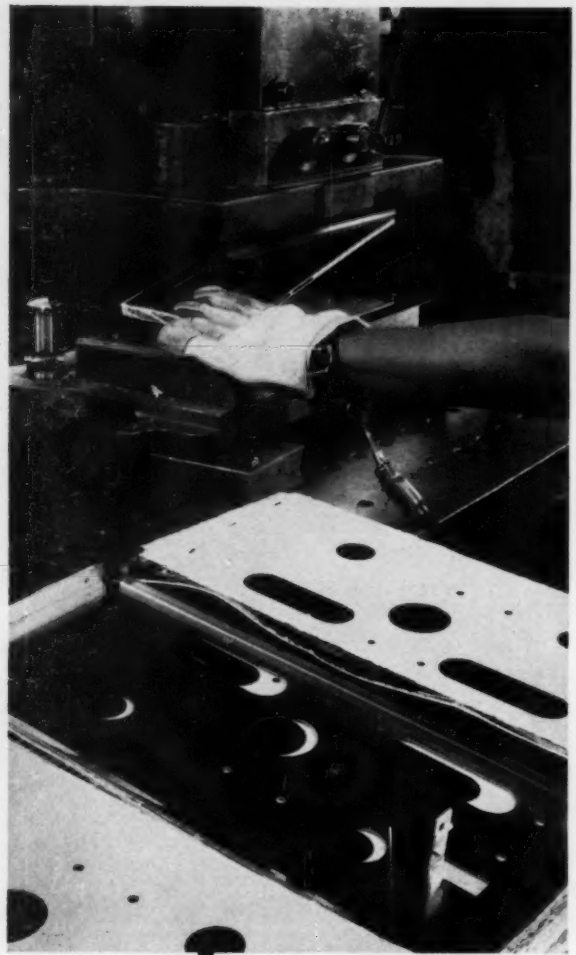


NO CLEANING

NO PLATING

NO POLISHING

a Vital Detail not caught by the Camera's Eye

The camera caught clearly the action of this die operation . . . shows the blanking and forming operation, the dies, other details. What the lens has missed is the gleaming, durable plated finish of bright polished Chromium over a steel base. This operation is typical; indeed, mass fabrication of this finished raw material is familiar to most shop men today. Nickeloid Metals have proved they can retain their lustrous beauty, even when stamped, formed, blanked, bent, riveted, soldered or welded. For severe fabrication, Mar-Not protective coating can be supplied to protect the lustrous surface from scratching . . . quickly peeled off after fabrication. Write us for "Introductory Kit," including metal samples.

NICKELOID METALS SINCE 1898

American Nickeloid Company
Peru 2, Illinois
Plants: Peru, Ill. and Walnutport, Pa.

Circle 1442 on Page 48-A

ACCURATE
DEPENDABLE
LOW COST

HEAT TREATING

with

YOUNG BROTHERS OVENS

designed and built for individual product and process requirements

batch and conveyor types up to 1000° F

Write for Bulletin 157

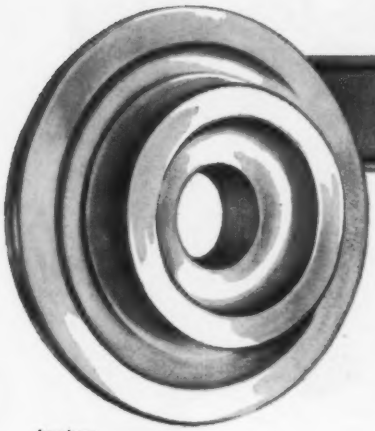
YOUNG BROTHERS CO.
1829 Columbus Road • Cleveland 13, Ohio
Over 60 years of service

Circle 1443 on Page 48-A

COLUMBIA TOOL STEELS

Confidentially, people who *make money* with non-deforming steel dies use EXL-DIE (Type O1) oil hardening steel

Product of Skilled American Workmen



Iron-base
high-temperature alloy
21½" diameter
244 pounds

FORGED

Titanium
24½" diameter
191 pounds

To speed the progress of gas turbine development

Nickel-base
high-temperature alloy
45" diameter
520 pounds

For applications ranging from automotive to aircraft propulsion, Wyman-Gordon is the world's largest producer of forged components for the gas turbine industry—turbine wheels, compressor discs, blades and vanes, for stationary turbines, nuclear installations, aircraft and missiles.

Wyman-Gordon's production experience includes forgings of a wide range of metals from low-alloy high-strength steels—titanium—intermediate temperature alloys—to the super-nickel-base alloys and refractory metals. *Guaranteed minimum properties* assure improved performance and dependability, and enable designers constantly to raise their sights and increase turbine capabilities.

With unexcelled research and production laboratories to concentrate on your development problems and with hammer and press capacity unequalled in the country, Wyman-Gordon is prepared to serve you in great depth at the design, engineering and purchasing stages of your requirements.

Titanium
15½" length

High-strength steel
19" diameter
143 pounds

EST. 1883

WYMAN-GORDON

FORGINGS

of Aluminum Magnesium Steel Titanium . . . and Beryllium Molybdenum Columbium and other uncommon materials

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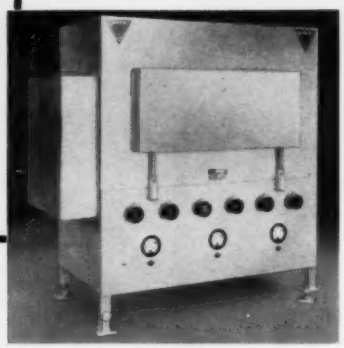
GRAFTON MASSACHUSETTS FRANKLIN PARK ILLINOIS LOS ANGELES CALIFORNIA FORT WORTH TEXAS

Circle 1367 on Page 48-A

PERECO rotary TUBE FURNACE



for

continuous-flow calcining or sintering

This Model RT-472 tube type unit is typical of a wide range of standard or special Pereco Tube Furnaces built for individual work requirements. It normally operates to a maximum of 2500°F (other temperatures available) and incorporates a 4⅛" I.D. x 72" long impervious Mullite ceramic tube; a ruggedly constructed gearing mechanism for variable tube rotational speed (0 to 6 rpm); and a simple arrangement for changing the degree of tilt to control the through-rate of powder-like materials of varying grain sizes, from entrance to exit end of tube. This is a quality unit of exceptional efficiency, designed specifically for delicate calcining-sintering processes. More details available on request.

Ask for Pereco recommendations on standard or special units for operating temperatures from 450° to 5000° F.

PERENY EQUIPMENT CO., INC.
Dept. Q 893, Chambers Road, Columbus 12, Ohio

Circle 1446 on Page 48-A

REVCO Sub-Zero Chests

- for shrink fits
- for seasoning gauges and tools
- for testing • for research
- for processing *to –140°*

Model RSZ503 Rivet Cooler (shown) equipped with 90 rivet canisters, temperatures to –30° F. 110V, 60 cycle, single phase.

Model SZH153 with temperatures to –95° F. 110V; 60 cycle, single phase.

Model SZH653, larger capacity, temperatures to –85° F. 110V, 60 cycle, single phase.

Model SZHC657. Same capacity as SZH653 but attains temperature as low as –140° F. 220V, 60 cycle, single phase.

Refrigeration: Model SZHC657 operates with 3 Tecumseh hermetic compressors in a two system cascade. Other Sub-Zeros use 2 hermetics in a two stage system. Rivet Cooler operates with single hermetic unit. All models equipped with efficient fan-cooled condensers—no liquid coolant required. *Write Today for Full Specifications and Prices.*

Description	Model	Cu.Ft.	Temp. Range		Outside Dim.			Inside Dim.		
			Rm. 70°	Rm. 110°	L	W	H	L	W	H
Sub-Zero	SZH153	1.5	–95° F.	–85° F.	42"	28"	42¾"	23"	9"	12½"
Sub-Zero	SZH653	6.5	–85° F.	–75° F.	60"	28"	42¾"	47"	15"	16"
Sub-Zero	SZHC657	6.5	–140° F.	–125° F.	60"	28"	42¾"	47"	15"	16"
Rivet Cooler	RSZ503	5.0	–30° F.	–20° F.	42"	28"	41"	30"	16"	18"

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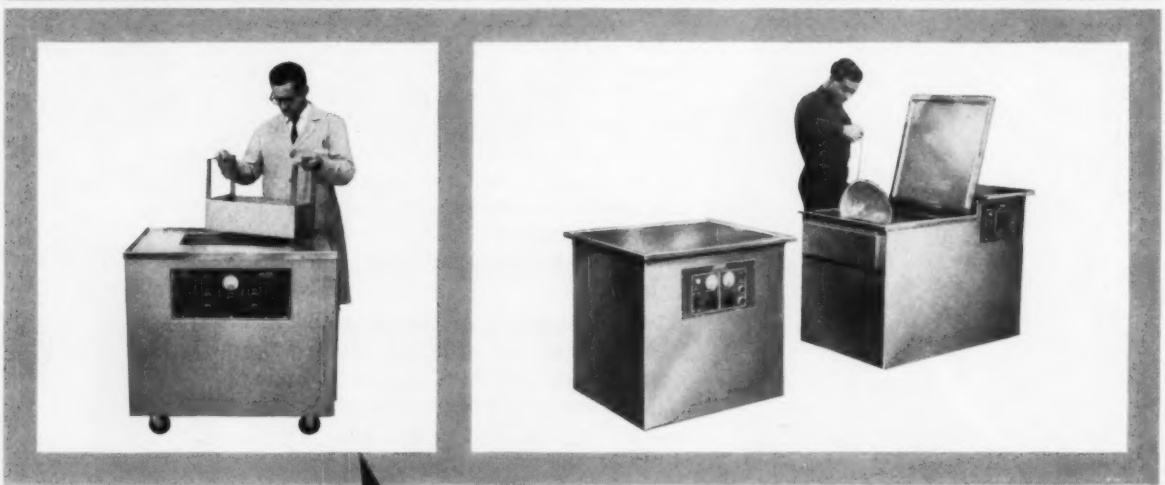

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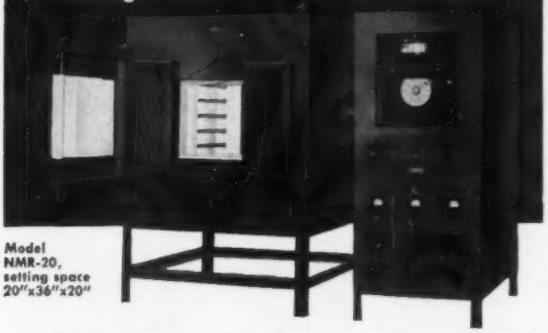

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BEHIND THE BYLINES

M. R. Scott's comprehensive articles on flame hardening (p. 69 through 75) are based on 20 years' experience in the manufacture and distribution of high-temperature gases and work on their use in steel processing. A graduate of Indiana University, he worked successively for the Carson Construction Co., Minneapolis-Honeywell Co. and Union Carbide Corp. until 1950 when he traveled to Japan to assist the Japanese Government on certain steel processing problems. Following his return a year later, he joined the Detroit Flame Hardening Co., and in 1954 became president of the company.

As an expert on flame hardening, Mr. Scott has talked on his subject before six A.S.M. Chapters; he's also a member of the A.S.M. Committee on Flame Hardening, in addition to the Technical Advisory Committee of the American Foundrymen's Society.

His varied technical interests are supplemented by a strong liking for golf and fishing.

The second author in our flame hardening section, John T. Howat (p. 76), has specialized in heat treating and flame hardening gears. He received his technical education in his native Scotland and after coming to the United States worked for Westinghouse, National Erie Corp., Pittsburgh Steel Foundry, and American Spiral Spring and Mfg., holding the position of superintendent of heat treating in all. In 1945 he formed the Pittsburgh Metal Processing Co., now one of western Pennsylvania's largest heat treating companies handling all sorts of commercial and atomic work.

Boats, sailing, fishing and traveling (not necessarily in that order) are his major interests. He has traveled through central Europe, along the eastern coast of the U.S. and in Florida, and now hopes to add the West Coast to his itinerary. But first he's planning a trip to the rest of Europe as a representative of the Pittsburgh Chamber of Commerce.

An "old-timer" in the vacuum induction melting industry, Joseph W. Byrne is beginning his fourth year in an industry less than ten years old. He came to the Metals Div. of Kelsey-Hayes Co. in 1956 as senior engineer for the 5000-lb. furnace project described in his article on

the "World's Largest Induction Furnace" (p. 83), where his duties included supervision of the Division's seven furnace installations and operations. Last September he moved over into marketing as production manager for industrial applications of the Division's superalloys and this is his present position. A graduate of Cornell with a degree in mechanical engineering, he began a two-year tour of duty with the Army in 1954 and was later assigned to the Detroit Arsenal as a project engineer; after his discharge, he joined Kelsey-Hayes.

Most of his free-time is taken up with duties as secretary of the Toastmasters Club; he has a well-deserved reputation as a gourmet specializing in foreign foods and beverages (which three trips to Europe helped cultivate). Golf and skiing also interest him.

The article on p. 87 is the first part of a two-part detailed report on "How to Get the Most From Solvent-Vapor Degreasing", written by T. J. Kearney and Charles E. Kircher, both of Detrex Chemical Industries, Inc., in Detroit. Mr. Kearney's entire career has been devoted to design, development and application of industrial equipment at Detrex; he has more than 25 patents in the metal cleaning field, the most recent ones in ultrasonic degreasing.

Dr. Kircher came to Detrex in 1952 following 14 years with Du Pont and five years as head of the department of chemical engineering at Rose Polytechnic Institute. Manager of research since 1955, his work centers on development, production and industrial use of chlorinated solvents and related chemicals.

Both authors are active in technical groups (including the A.S.T.M. Committee D26 on halogenated organic solvents). Mr. Kearney's interest centers on reading and alumni activities (he's a 1934 graduate of the University of Detroit). Dr. Kircher's spare time activities – largely controlled by the interests of six children – include tennis, golf, archery and swimming. His interest in teaching is maintained by giving graduate instruction in chemical engineering subjects.

James G. Goodwin, author of the first article on Zircaloy-2 in our nuclear reactor technology section (p. 93), has been working in the atomic power field since July 1951 when he joined the Bettis Atomic Power Laboratory, fresh from Penn State. His work has included the development of melting and fabrication techniques for uranium, hafnium and zirconium alloys (one phase of which is covered in the article) and he is now with the special materials section of the Bettis nuclear core department in Pittsburgh.

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Behind the Bylines . . .

The problem of what to do with the millions of pounds of zirconium scrap remaining after fabrication operations is resolved by B. F. Rubin and R. F. Gessner in our second Zircaloy-2 article, "Recycling Zirconium Scrap", on p. 97. Mr. Rubin has been affiliated with the Bettis Atomic Power Laboratory since 1955 and is currently studying irradiation effects on fuel materials with the ceramics irradiation group of the reactor metallurgy department. Mr. Gessner joined Bettis shortly after

Authors Gessner (Left) and Rubin Standing Before an Atomic Symbol

it was founded in 1950; he is now attached to the nuclear core department's core engineering section, working on the evaluation of metal powder alloys.

When asked what their special interests were, each author replied, "School and children". Both are attending night metallurgy classes – Mr. Rubin at the University of Pittsburgh and Mr. Gessner at Carnegie Tech. As for children, Mr. Rubin's number four and Mr. Gessner's three.

Since coming to Damascus Tube Co. six years ago, Byron B. Burd's chief concern has been the development of better quality control over all mill operations. An intensive investigation in the field of instrumentation by Damascus led to the development of the Damascope, discussed in his article on p. 101.

His family (wife, four children and two cats) keeps his spare time well occupied. He teaches Sunday School every week and when time and weather permit takes the family boating and fishing. His children, though, are more impressed by his once-a-year stint as end man in a minstrel show produced by a civic group. When a stranger asks their father's occupation, they can sometimes be heard to say proudly, "He's an end man in a minstrel show."

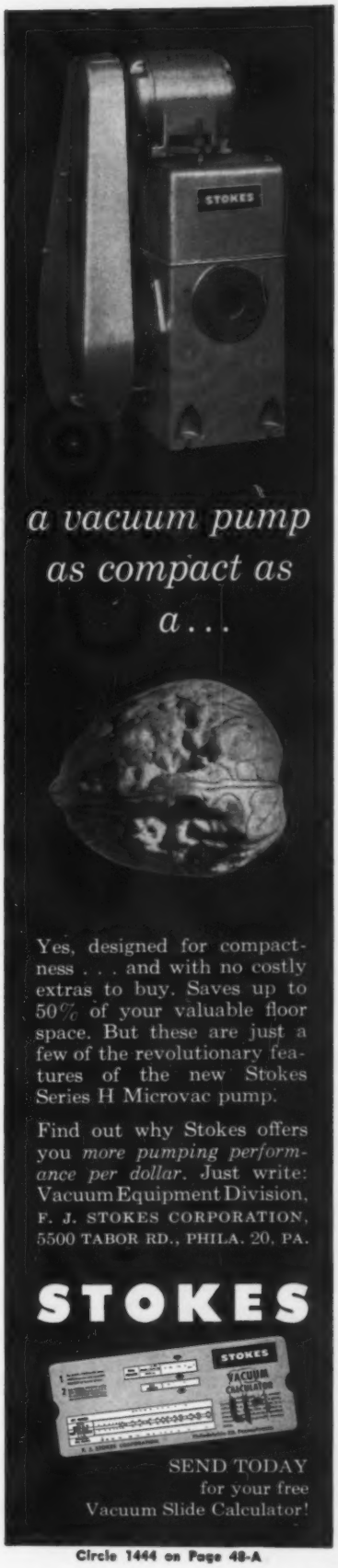
Merrill A. Scheil's report on the stability of chromium stainless steels after eight years at high-temperatures (p. 104) is based on his work at the A. O. Smith metallurgical research laboratory. During over 30 years at A. O. Smith, he has pioneered in the use of plain polarized light for the identification of inclusions in steel, fractional vacuum fusion for gases in steel, and was an investigator of the early studies in stress-corrosion cracking of stainless steel. His current work has been on the corrosion properties of austenitic weld metals and wrought alloys and the long-time stability of materials in regard to strength and corrosion at elevated temperatures.

Merrill Scheil (Left) and H. F. Ebling Study Model of Corrosion Data for Austenitic Welds

Currently a trustee of A.S.M., he has spent a good deal of time in the past 20 years as chairman of the Milwaukee Chapter, on the Metal Progress Advisory Committee, and on special Handbook committee assignments.

Merrill has been going to the Door Peninsula for 35 years where his wife and two children spend the month of August in the waters of Green Bay. He sails a rubber boat (Klepper) which looks like a kayak. One of the trickiest boats in the bay, it never fails to attract attention, especially when sailing in very shallow water.

The article on a new iron-base high-temperature alloy by George K. Manning is based on data obtained during a research program sponsored by Kennecott Sales Corp. at Battelle Memorial Inst. Now chief of the Metallurgical Engineering Division, he has been with Battelle 17 years where his research activities have included such areas as high-temperature alloys and ferrous alloys. A B.S. degree from Franklin College and a M.S. from the University of Michigan set the foundation for his professional career.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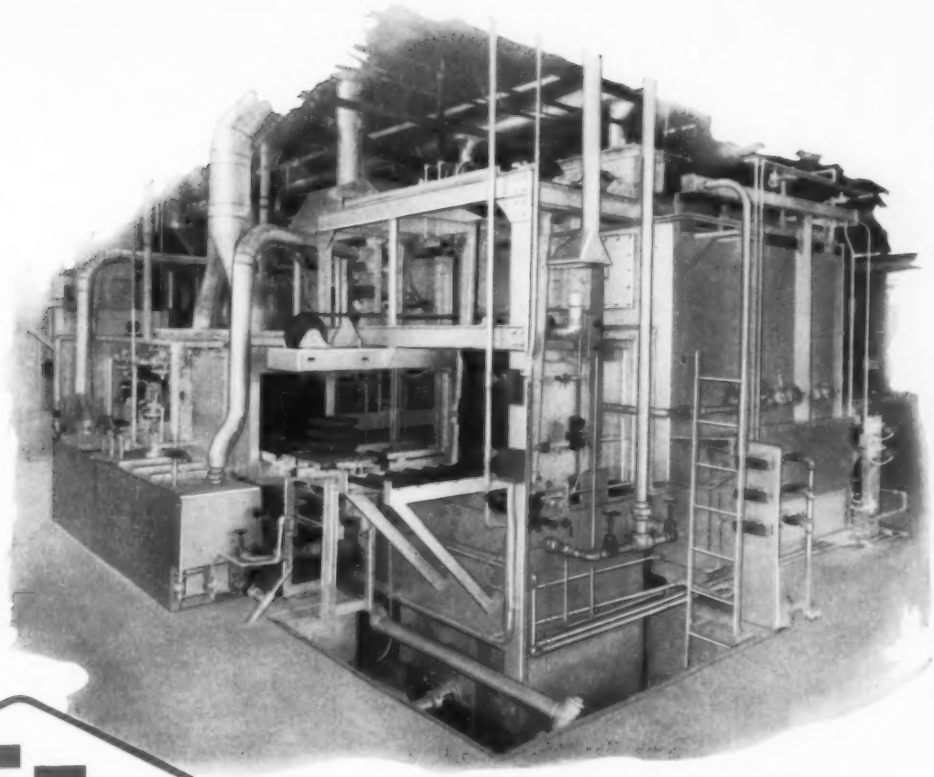

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OPEN-HEARTH SAVINGS — Steelmakers are changing the form in which chromium is added to [illegible] open-hearth constructional alloy steels. Melters are switching to ferrous additions [illegible]. Recent surveys of [illegible] show savings of $1.85 to $2.50 per ton in chromium and [illegible] Union Carbide's [illegible] replaces expensive ferrous [illegible] additions and [illegible] needed for blending. Your [illegible] Carbide Metals representative [illegible] to give you additional information.

[illegible] — Steelmakers [illegible] melters continue to be surprised when they [illegible] "Simplex" ferrosilicon. In a typical heat, [illegible] (7.4 per cent chromium) dissolved in a [illegible] after [illegible] than 40 minutes. In addition, 300 [illegible] of [illegible] during refrigerated [illegible] at 0°F. [illegible] Write for F-20,410.

OPTIONS AID [illegible] — Users of 50 per cent ferrosilicon, standard and medium-carbon ferromanganese, and ferrochrome-silicon are now [illegible] [illegible] specifications. Users report 10 to 20 per cent higher recoveries with [illegible] alloys in the ladle, cutting alloy costs. In addition, buyers give closer control over specifications, cut [illegible], and aid inventory control. Union Carbide Metals produces 11 options in all. For wider and closer [illegible] specifications and color, write for F-20,[illegible].

QUALITY IN QUANTITY — Each of the more than 100 "Electromet" ferroalloys and metals is [illegible] during every step of production. The aim: To make sure that each alloy meets [illegible] specifications consistently. Samples are taken during raw material preparation, furnacing, stamping and crushing, packing, storage, and shipping. During an average month at Union Carbide Metals' Marietta, Ohio, plant, more than [illegible] tests are made on over [illegible] samples. For further details, see for the Summer 1960 issue of UNION CARBIDE METALS REVIEW.

SAVINGS GROW WITH [illegible] MANGANESE-SILICON — Several [illegible] melters have reported that adding ferromanganese-silicon for slag reduction has increased the recovery of chromium from the slags. A drop of as much as 4 per cent in the chromium oxide content of the slag has been reported. To a melter charging 12 per cent chromium, a one per cent chromium recovery means a saving of 2.4 lbs. of chromium per ton of low-carbon ferrochrome, worth about 75 cents per ton. These savings are in addition to those previously reported — $4 to $6 per ton for 300 series stainless and $0.75 to $1.75 per ton for 300 grades. Further facts are in a [illegible] folder, F-20,095.

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"Electromet," "Simplex," and "[illegible]" are registered trade marks of Union Carbide Corporation.